ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

VOL. XLIV. No. 2.

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A CIVIL SERVICE EXAMINATION will be held July 16 for the position of Inspector of Steel for the Rapid Transit Commission, New York city. The subjects of the examination are technical knowledge, arithmetic, experience and handwriting. Candidates need not be residents of the State, but their vouchers must reside in the city of New York, or have a business address therein. Appointees will be required to reside at the places where the mills having the contracts for the steel work are situated. Similar examinations for inspectors of cement, inspectors of pipe making and measurers, will be held July 19, 27 and 31, respectively. Particulars may be obtained by addressing Mr. Lee Phillips, Secretary, Municipal Civil Service Commission, 346 Broadway, New York city.

FREIGHT RATES AND CLASSIFICATION were discussed recently at a meeting between representatives of commercial organizations and members of the Southern Classification Committee, at Chicago. Arguments protesting against the action of the committee in again advancing numerous items in the merchandise classes of freight were presented. The group of roads south of the Ohio River and east of the Mississippi River, in February, followed the example of the Official and the Western classification committees in issuing a new form of classification list, the general effect of which was to advance the freight charges on some 1,500 items about 30%. In response to numerous protests, the classification was re-issued on June 1, in a further revised form, reducing the general advance to 20%, but raising higher in class nearly 400 more articles. The Merchants' Association of New York strongly opposed the advances in Southern freight rates, and its representative stated that it was not believed that transportation conditions in Southern territory justified the exaction of higher rates. He quoted the rates in effect from New York to Chicago and from New York to Atlanta, the mileage in the latter case being less than in the former, while the rates are much higher:

	N. Y. to Chicago.	N. Y. to Atlanta.
Distance	913 miles.	874 miles.
First class rate	$0.75	$1.14
Second class rate	.65	.98
Third class rate	.50	.86
Fourth class rate	.35	.73
Fifth class rate	.30	.60
Sixth class rate	.25	.49

It was also stated that the new classification showed 75 additional distinctions made between "carload" and "less than carload" shipments by advancing the classes of the latter, all of which were said to be discriminations in favor of large shippers and against buyers of small lots. It was evidently the aim of the Merchants' Association of New York to impress upon the members of the committee the fact that it was determined to obtain relief from the conditions that had been established, for the protest stated that if the committee did not recede from the position it had taken, its decision would not be regarded as concluding the matter. The association is said to be prepared to show that the freight charges resulting from the committee's action are not only unreasonable, but are also discriminatory as between shippers and localities, and are thus necessarily in restraint of trade.

HIGH-LIFT CANAL LOCKS were considered at the second meeting of the Board of Consulting Engineers for high-lift locks for the canals of New York State, held at Albany, N. Y., July 2 and 3. The last Legislature appropriated $200,000 for the surveys and investigations necessary to a full consideration of this project, and it is intended by the State Engineer, Mr. Edward A. Bond, to submit the whole subject to the next Legislature in January, 1901, there being now 20 survey parties at work. At the former meeting, the attention of the Board was mainly given to the details of the Dutton pneumatic lock, which had received favorable action by the canal authorities in 1896. At the second meeting plans were presented by the Buffalo Engineering Co., represented by Mr. Chas. M. Morse, M. Am. Soc. C. E., of Buffalo, N. Y., and Mr. Thomas Ellis Brown, Jr., M. Am. Soc. C. E., Consulting Engineer of the Otis Elevator Co., for cable counterpoise lift-locks and for hydraulic lift-locks. The present plan for counterpoise lift is a modification of plans presented by the same company in 1896; the original plans provided for a movable tank or lock-chamber balanced by a counterweight; while the present plans provide for balancing one lock-chamber with another similar chamber; the two connected by a large number of wire cables passing over sheaves and drums connecting the tanks and having safety appliances to prevent drop in case of breakage. Sketch plans for a hydraulic lift were also presented, which provide for two lock-chambers or tanks, each supported and raised and lowered by three plungers worked in three cylinders; the two locks counterbalancing each other through the water-connections of the two sets of cylinders. These plans include a simple and novel device for preserving the level position of the lock-chambers or tanks, and for preventing one end of the moving tank from raising or lowering more rapidly than the other end, a difficulty said to have created serious trouble with locks of this type constructed abroad. The Board also considered plans for a counterpoise lift-lock, designed by Mr. Wm. H. Davis, Assoc. M. Am. Soc. C. E., and Chief Bridge Designer of the State Engineer Department. This device consists of a pair of tanks counterbalancing one another, and supported and raised and lowered upon twelve steel towers supporting 24-ft. sprocket wheels, over which travel flat-link chains. These lock-chambers each have inside dimensions of 310 × 28 ft., with 11 ft. of water, and weigh, when loaded, whether with boat or without boat, 5,500 tons each. These tanks are raised and lowered by electric power developed by turbine wheels; the power being automatically cut off when the tanks reach the proper level, and the machinery being so interlocked as to prevent any movement of the machinery until the lock-gates are fully closed or fully opened and the boats have entered or left the lock-chamber, the lock-chamber or tanks being immovable when the gates are open. The Board also gave much time to the consideration of sets of ordinary masonry lift-locks and to the subject of comparing the amounts of water and of time needed for the operation of different locks. In considering ordinary lift-locks, it appears that there is no need for any single lift exceeding 27 or 30 ft., although the Board would not hesitate to advise using higher lifts than 30 ft., if the conditions favored it. The Board is composed of the following members: Mr. Elnathan Sweet (Chairman), former State Engineer; Major Dan. C. Kingman, Corps of Engineers, U. S. A.; Mr. George S. Morison, M. Am. Soc. C. E., and member of the Isthmian Canal Commission; Major T. W. Symons, Corps of Engineers, U. S. A.; Prof. W. H. Burr, of Columbia University, and member of the Isthmian Canal Commission.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the Delaware, Lackawanna & Western R. R. at Henryville, Pa., on July 4. Two cars on an eastbound freight train were derailed on a down-grade, and a westbound fast freight crashed into the wreck. Three men were killed and one injured.

AN EXPLOSION OF GASOLENE TANKS in the yards of the Ohio River R. R. at Parkersburg, W. Va., on July 4 is reported to have caused the death of six persons and the injury of many others.

A STREET RAILWAY ACCIDENT, accompanied by great loss of life and exceptional horror, occurred at Tacoma, Wash., on July 4. A crowded car became uncontrollable on a heavy grade leading down to a bridge over a deep ravine. Rushing down the hill with great speed it was thrown violently from the track at a sharp curve on the approach to the bridge and, falling 75 ft. through the air, it was smashed to pieces on rocks projecting from the side of the gulch, the wreckage of the car and the dead and dying rolling 50 ft. farther to the bottom of the gulch. Few of the passengers escaped injury; 41 were killed outright, or died soon after the accident, and 62 were seriously injured.

LIGHTNING struck a crude oil storage tank of the Standard Oil Works at Constable Hook, near Bayonne, N. J., on July 5. From it the fire spread to nearby tanks and raged for three days before it could be subdued, wiping out nearly the entire plant. Twenty-four tanks were destroyed, and the loss is estimated at $2,500,000.

AN ELECTRIC CAR of the Third Ave. Ry. of New York city became uncontrollable on a hill on Amsterdam Ave. on July 10, and attaining a high rate of speed collided with two cars in front of it. Seven persons were injured and the three cars were badly wrecked.

SHORT SIX-BOLT RAIL JOINTS are proposed for the Union Pacific Ry. by Mr. J. B. Berry, Chief Engineer. The splice bars will be 29 ins. long, the middle bolts being spaced 5 ins. c. to c., and the others 4½ ins. c. to c. The weight of the bars, per pair, will be 55.7 lbs. for 80-lb. rails, and 65.3 lbs. for 90-lb. rails. The old joints have bars 26 to 40 ins. long, with four bolts, 6 ins. c. to c., the bars weighing 50 to 58.5 lbs. per pair.

A TRESTLE ACROSS THE GREAT SALT LAKE, in Utah, is projected as part of a cut-off line to be built by the Southern Pacific Ry. (under the charter of the Ogden & Lucin Ry.), at a cost of about $5,000,000. The total length of the short line from Ogden to Lucin will be 100 miles, with exceptionally easy grades, while by the present line (which follows around the shore of the lake) the distance is 145 miles, and has heavy grades. The elevations above sea level are 4,300 ft. at Ogden and 4,700 ft. at Lucin. The Southern Pacific Ry. will also spend about $4,000,000 in improving grades and alinement, including entire reconstruction at some points.

THE IMPROVEMENT OF THE YAZOO RIVER, for which bids were opened June 28, consists in excavating about 7,500,000 cu. yds. of earth for the purpose of giving a new mouth or outlet for the various streams forming the Yazoo system to the Mississippi River, which will be navigable at all seasons. The harbor at Vicksburg will also be restored. The route will be from the junction of the Yazoo River proper with the former bend of the Mississippi River (1797-1808), about 9.8 miles above the present entrance of the Yazoo into the Mississippi. It will cut through a neck of low land from Old River to Lake Centennial, and pass around the head of De Soto Island and down the former channel of the Mississippi River (1876), in front of the city of Vicksburg to deep water in the bend of the river at Kleinston Landing. The length of the route will be about 9.31 miles. The bids opened on June 28 by Mayor Thomas L. Casey, U. S. Engineer Corps, at Vicksburg, Miss., were as follows: Atlantic, Gulf & Pacific Co., New York, N. Y., 12.4 cts. per cu. yd., $930,000; Rittenhouse-Moore Dredging Co., Mobile, Ala., 12.9 cts., $967,500; Bowers Southern Dredging Co., Galveston, Tex., 13.25 cts., $993,750. The contract has been awarded to the first named company.

AN ISTHMIAN CANAL ON THE DARIEN ROUTE is proposed by a new company, the American Isthmian Canal Co., the Chief Engineer of which is Mr. Edward W. Serrell. The canal proper will, it is said, be only 29½ miles long, but the distance from ocean to ocean, which is the important feature, is not stated. It will be a sea level canal. The proposed route is known as the Mandigo-Darien route, and is said to be across comparatively low country, except for seven miles, where the mountain range will have to be tunneled. The project appears to be very similar to that for the old San Blas route.

THE TORONTO (ONT.) HARBOR IMPROVEMENT has recently been reported upon by Messrs. Roy and Jennings, engineers, and various improvements are suggested, including jetties for a 20-ft. channel at the eastern entrance, and a new channel, 125 ft. wide, 14 ft. deep and 4,800 ft. long, across Ashbridge's Bay, with lateral channels across the marshes. The great amount of sand brought down by the Don River is to be diverted from the harbor and utilized to fill in the marshes. The estimates are as follows: Eastern entrance improvements, $256,000; western entrance, $21,000; new channel, $80,000; improving Ashbridge's Bay and Don channels, $100,000; groins for protecting the Island beach, $150,000; dredging the harbor, $140,000; filling in for "made" land, $427,000; total, $1,174,000.

A 20,000,000-GALLON WATER FILTRATION PLANT for Providence, R. I., has been recommended by the joint special committee of the city council on filtration. The committee recommends the appropriation of $176,000 to pay for the improvement, and also that the mayor be requested to appoint a commission of three to ascertain the cost, including riparian damages, of developing a new supply from the Pawtuxet River, above the chief sources of pollution.

A CABLE-LAYING STEAMER, the "Von Podbielski," has recently been built for the North German Cable Co. by David J. Dunlop & Co., of Glasgow, Scotland. The vessel is 235 ft. long and 35 ft. beam, with a carrying capacity of 1,300 tons on a draft of 16 ft. 6 ins. There are three cable tanks, of about 25,500 cu. ft. capacity, and water ballast tanks of 300 tons capacity are also provided. The vessel has twin screws, driven by triple expansion engines, designed to give a sea speed of 13 knots. At the bow is a combined paying-out and picking-up machine, while a paying-out machine is placed aft.

SOME RECENT TRENCH EXCAVATING MACHINES.

Machines for removing and conveying the earth excavated by hand in sewer trenches have been used quite extensively on important work with large trenches, and have been described in our columns. In the present article, however, we refer to machines for excavating smaller trenches for pipe sewers and tile drains, without the use of manual labor.

The first machine which we shall describe is that

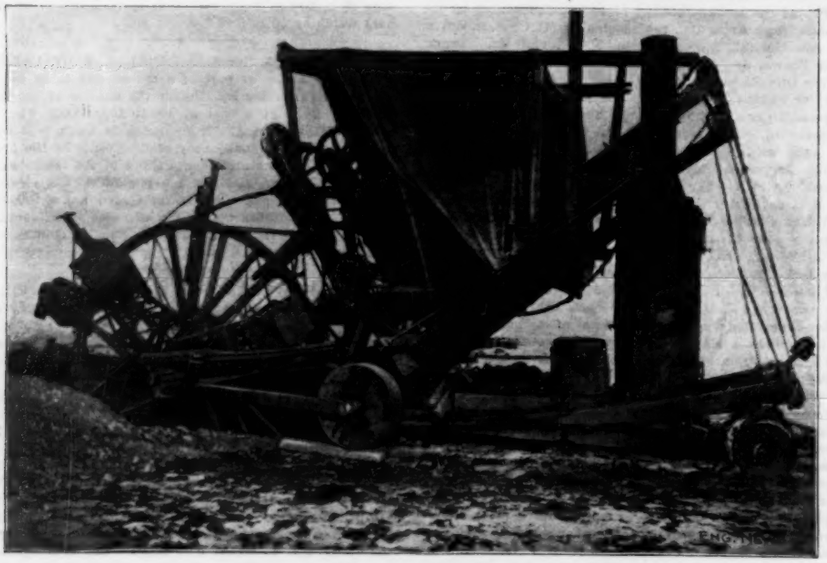

FIG. 1.—TRENCH EXCAVATING MACHINE.
Richard Dalton, Inventor.

invented and built by Mr. Richard Dalton, of Wilmette, Ill., and which has been used on two pieces of work by John A. McGarry & Co., contractors, 189 Racine Ave., Chicago. It is a rather crude-looking machine, being "home-made" and the first one built, but it has done satisfactory work, and is believed to embody the essentials of a successful machine. Fig. 1 is a side view of the machine, and Fig. 2 a rear view, showing the trench. The machinery is mounted on a wagon bed, fitted with road wheels. The excavating is done by a series of plows attached to the radial arms of a wheel 12 ft. in diameter, driven by a sprocket chain which runs on the rim of this wheel and on a smaller sprocket wheel on the engine shaft. This wheel is at the rear of the machine. On each side of the wheel are four buckets, attached to hinged radial arms, whose inner ends are pivoted near the axle of the wheel in such a way as to be able to swing laterally. Plows on the wheel extend a little ahead of the mouths of the buckets. As the wheel rotates, the plows loosen the material, which falls away from the plow into the bucket. The radial arms carrying the buckets are automatically locked during the operation of filling. As each bucket reaches a level a few feet above the top of the trench, the lock is disengaged, and the arm swings out sideways, the revolution of the wheel causing the bucket to dump its load. As the revolution continues, the arm swings back against the wheel, and is locked in position to pick up another load. The machine is hauled by a chain about 300 ft. long, the end of which is attached to a post or deadman, the chain being wound upon a ratchet drum operated from the excavating wheel. The trench or ditch can be made 30 to 72 ins. in width, and the present machine will excavate to a depth of about 9 ft.

The Dalton machine was first used in January by John A. McGarry & Co., on 1¼ miles of sewer trench and 1¼ miles of water pipe trench at Wilmette, Ill. The trenches averaged 3 ft. in width and 6 ft. in depth, and were cut through material ranging from solid hard-pan to black loam that would hardly stand long enough for the sheeting and bracing to be put in. Under these conditions, however, the machine gave good satisfaction, and its work averaged about 400 ft. of ditch per day. It made this progress in one day of nine hours when digging a trench of the above dimensions in gravel frozen to a depth of 20 to 24 ins. It was operated by an engineman, fireman and two laborers. The same firm later used the machine for cutting a sewer trench 1,600 ft. long, 3 ft. wide and averaging 7 ft. in depth at North Evanston, Ill. Here the same rate of progress was made with the same number of men, and with a consumption of ½ ton of coal per day, although the ground was frozen to a depth of 18 to 20 ins.

The Austin ditching and trenching machine has a steel frame, consisting of a pair of channels or I-beams pivoted to supports on the rear end of the wagon bed, and carrying at its end a 12-ft. wheel having two rows of steel buckets attached to the periphery, these buckets excavating the material like the buckets of a ladder dredge. On the end of the frame are two chutes, the upper ends of which are level with the top of the wheel, and the buckets dump their contents over these chutes. The broad rim of the wheel is sloped to each side of the center line, thus helping to divert the material into the chutes. A vertical boiler is mounted at the front end of the wagon bed, and an 8-HP. vertical inverted engine at the rear, the engine driving the excavating wheel by means of a link belt passing round the periphery of the wheel. The sides of the trench are trimmed to any desired shape by means of adjustable blades on the wheel. A machine of this size will cut a trench to a depth of nearly 6 ft., 3 ft. wide at the top and 12 to 34 ins. wide at the bottom. Smaller machines, operated by steam or horse-power, are adapted for digging trenches for tile drainage. The machine hauls itself along by means of a wire cable wound on a drum and anchored some distance in advance. Another machine closely resembles that above described, except that the wheel is replaced by an inclined boom carrying a chain of small buckets (in pairs), and operating like a ladder dredge.

Still another system has been called to our attention, in which a traction engine was used, being fitted with a winding drum and wire cable. The cable was attached to a breaking plow, and then to a specially shaped scoop. Behind the engine was a crane or hoisting jib, by which the scoop was raised to the surface, and dumped into a wagon. This machine was employed on two miles of heavy trench work for the main outlet sewer at Frankfort, Ind., by Pilcher Brothers, contractors, of North Baltimore, O. The 8-HP. hoisting engine and the hoisting apparatus were made by J. S. Mundy, of Newark, N. J. The material was variable, being glacial drift composed of blue clay, yellow clay, hardpan, gravel, sand, boulders and quicksand. The trench was about 5 ft. wide, and for a distance of 2,000 to 2,500 ft. its depth was from 25 to 30 ft. According to our information the machine did its work well but was not economical in operation.

A machine designed for similar work, but never as yet put in service, has been patented by Mr. Harvey C. Lowrie, M. Am. Soc. C. E., of Denver, Colo. The wagon bed supports two A frames to which is pivoted an inclined beam, the bottom of which is curved backwards and is horizontal for a short length at the bottom of the trench. Beams projecting behind the wagon bed carry the operator's platform. The inclined beam is formed of two channels set back to back and connected by bracing. On the lower flanges run trolleys carrying a plow and a bucket or scoop, which are operated by chains on drums driven by the engine. The level of the bottom of the beam can be adjusted to suit the grade and depth of trench, and the plow and scoop in being hauled up cut and remove material from the breast of the trench, the bucket then dumping the load at the sides of the trench. A small machine now being tried experimentally has a double track incline with two balanced scoops, one ascending and the other descending. It is operated by horse-power, and is designed to dig to a depth of 10 ft. and a width of 28 ins., discharging on either or both sides, into wagons or upon the ground at the side of the trench. Mr Lowrie states that he considers his large machine to be adapted for economical work on large and deep excavations and dredging, as for canals, placer mining work, etc.

POWER TRANSMISSION BY SHAFTING VS. ELECTRICITY.*

A comparison of the relative advantages of electricity and shafting for driving for shop use may be made under the following general headings: (1) Relative economy in cost of power itself; (2) relative convenience of operation and installation; (3) relative effect upon shop output and cost of labor.

Economy.—This has been taken to comprehend only the relative cost of operating the two systems, including expense for fuel, attendance, repairs, interest on investment

Fig. 2.—End View of Trench Excavating Machine.

and depreciation. It is the reason most generally advanced for the installation of electric power, but can only be the controlling one where the cost of power is a large proportion of the shop running expenses. In order to compare the relative efficiencies of engine and electric transmission, it will be necessary to subdivide the charac-

*Abstract of a committee report presented at the convention of the American Railway Master Mechanics' Association: George Gibbs, F. Mertsheimer, William Renshaw, W. A. Nettleton and R. A. Smart.

ter of shop plants somewhat. To do this completely would lead to endless complication, but for present purposes the typical plants are:

1. Shop plant in which each building has its own power plant.

2. Shop plant in which all buildings are furnished with power from a central source.

The manner of connection from the prime mover to the tools may be assumed, for an extreme comparison, in either of two ways, namely: (A) shafting method; (B) individual tool-driving method.

Taking the first condition, the average efficiency from engine to tools for steam engine transmission is shown elsewhere to be 50%; for electric transmission, under condition "A" the shafting losses will be reduced by splitting up long lines and by avoiding cross-belting, so that they will not exceed 20%, or an efficiency of 80%; and in the electrical elements, as before shown, the efficiency from engine to shafting is 65%; therefore the final transmission efficiency will be, $80 \times 65 = 52\%$, as against 50% in the purely mechanical method. Under condition "B," much less shafting will be employed, and the electrical portion may also show a better all-day efficiency, under certain conditions, by the shutting down of idle machines —say, a shafting efficiency of 90% and an electrical efficiency of 66%, or a resultant of 60%—showing a small gain for the electrical method.

Taking the second condition and assuming an unfavorable condition for shafting transmission, as in case of a shop having each building with its own boiler plant and one or more engines, and compare this with a case of a central power plant for electric transmission to all buildings, the possible fuel saving in the latter arrangement will result first, from some small saving in power required for each individual building, as before shown, and second, from some very considerable saving due to the better efficiency of a large engine and boiler plant over that of several small ones. In extreme cases, where large condensing engines displace small non-condensing ones, and in large stations having a uniform load, the fuel saving may readily approximate 33⅓%, as is shown in an actual case cited elsewhere.

Attendance.—The item of attendance is made up of three classes of labor: Engineers and firemen; care of shafting and belting; electrical repairs. In an electric system the costs can be reduced by consolidating the engine and boiler plants and by the elimination of large and heavy belts, large shaft bearings and the consequent danger from overheating, reducing labor probably one-half; but a new item of expense in care of electric machinery will be introduced, which will about effect the other items, leaving the whole attendance bill practically unaffected by the introduction of electric shop power in plants of any considerable size.

Repairs.—As to repairs of shafting and belting it is difficult to obtain accurate data, the record of these items being seldom kept separately in shop accounts. The records of one large establishment have, however, been examined by your committee and the saving found in these items, under the electric driving system, is found to be more than sufficient to pay for all repairs to motors and lines. Thus the conclusion seems justified that the repair item will not be materially different under either system of driving.

Interest.—The remaining items of power-cost are depreciation and interest on investment. It is difficult to institute a fair basis of comparison between the first cost of an electric and a steam transmission plant, for the reason that the results sought to be accomplished by the former provide additional shop facilities, and are therefore not rightly chargeable in a substitution sense. Considering, however, the case of simple substitution in a single shop, where the power plant and arrangement and number of tools is retained as before, electric driving is certain to involve a largely increased first outlay—approximately double that for shafting method. But in a modern shop plant other considerations are the guiding ones in selection of the power system, such as the possibility of labor-saving devices, cranes, etc., and the greater cost of the electric system becomes a rightful charge against the advantages so obtained.

Dropping, therefore, any attempt to draw a strict comparison between first costs, it may be said that in estimating the total cost of power machinery, it is usual to include an allowance for interest and for a sinking fund, with which to replace the plant when its utility is no longer on an equality with best practice. These items are generally figured together at 10% on first cost, a sum amounting roughly to one-fourth of the total running expenses of the power system.

Convenience and Shop Output.—The ordinary shop plant with steam power transmission, both in the arrangement of building and of machines, is the slave to the limitations of this system; it must be laid out so that the shafting and engine connection is as direct and simple as possible; the machines must be compactly arranged in parallel lines, and the ceilings and columns designed with special reference to shafting supports. In other words, the tools must be installed with first reference to the application of power and not, as should be the case, with reference to handling the work to best advantage. Handling operations are of necessity largely by manual methods, and the shop buildings even must be located with first view to getting the power to them with the least awkwardness and expense. While generalizing in this manner, your committee has not lost sight of the fact that handling and transferring machinery may be operated by other means than electricity, but it is equally true that devices of this nature are of limited practical application, and the broad fact remains that electricity is to be credited with ushering in a new era of labor-saving shop devices.

Electrical transmission places no restriction on the location of the machines, and each shop may be planned with a view to handling its product with least waste of labor and with greatest convenience of access to the tools. These may even be transported from place to place to the work; further, the partial or entire absence of overhead line-shafting insures better lighting of the shop and conduces to cleanliness. These factors promote cheerfulness and an improvement in both quantity and quality of output.

The clear head room permits the universal application of various forms of traveling cranes for serving the tools and for conveying operations, furnishing the most efficient means yet developed for increasing shop economy, and, as a means of communication between buildings, electric cranes and transfer tables have advantages over appliances of the same nature driven by steam and air.

Special Appliances.—In these electricity shares a large field with compressed air. It must be admitted that air devices have up to the present time received most attention at the hands of the railway mechanic, a fact in large part due to the lack of practical knowledge of the electrical specialist and to the greater cheapness of air tools. With, however, the general introduction of electric shop power plants and the better acquaintance of practical men with the agency, an extensive application of electric labor-saving devices is certain to result.

Flexibility.—The extension of a shop building or the tool equipment under the shafting system is generally a matter of much difficulty, and the attempt to add to such a plant often results in inconvenient crowding of the tools or to an overloading or complication of the shafting system, a fact which fully accounts for the extremely poor efficiency sometimes quoted for shafting transmission. In an electric system, on the other hand, great flexibility in extension is secured, as new buildings may be placed in any convenient position and additions made to the driving system without affecting the intermediate links.

Speed Control.—The ease of speed control between wide limits of certain types of electric motors is a valuable feature and will result in more frequently securing a greater adaptability of the tool to the work than is possible where a change in speed involves stopping the tool and shifting belts and gearing.

Increase in Output.—This constitutes, in the opinion of your committee, the chief claim of electric transmission to the attention of shop managers, and it follows from the previously mentioned facts, as, by the use of electric-handling devices, the tool is quickly served with its work and the product placed in the most favorable position for operating upon and idle time cut down, and, by independent driving, the capacity is increased by reason of the perfect control of speed possible.

Power Required to Drive Machine Tools.

Data for power required for shafting and for certain tools may be found scattered through the transactions of various engineering societies, especially in the papers of Prof. Benjamin, in the proceedings of the American Society Mechanical Engineers, 1896 and 1897, which gave valuable figures; but the amount of exact information attainable anywhere is not very considerable. In the nature of things, figures for frictional losses in shafting must be exceedingly variable, and under the plan of connecting the shop power system to one main driving engine, there is no ready means of analyzing the figure of engine-indicated horse-power to determine the consumption of any particular section of shaft or of a single tool. With the introduction of electric driving, however, the subject is becoming better understood, as it is a simple matter to connect a test motor to a shaft or tool and thus obtain figures from which to design a power plant for maximum efficiency.

Electric Efficiency.—An electric transmission plant varies in efficiency as follows: Generators, 86 to 90%; transmission lines, 90 to 95%; motors, 78 to 80%; total final efficiency, 62 to 77%.

The above are figures for full loads on the different elements and the variation arises from the difference in sizes of units employed and in line losses assumed. At partial loads the machine efficiencies will drop, but the line efficiency will increase, so that the resultant will be nearly independent of the load. In fact, it is generally possible to shut down many of the separate motors when operating the plant at partial load, and the efficiency of transmission may thus actually increase under such conditions. In an average size of railway shop plant a resultant all-day efficiency of 65% from the engine to the motor pulley may be assumed.

Shafting Efficiency.—The average friction horse-power in heavy-machinery shops to drive belts and shafting, from engine to tool pulleys, as given by various authorities, varies from 40 to 55% of the total power used, and perhaps the round figure of 50% is as near the correct general average as the data will permit. Considering a separate shaft only, with compactly arranged tools, a better efficiency than the above can be assumed, and your committee concludes from a number of experiments with electrically driven line shafts that 20% fairly represents the average loss in shaft and counter-shaft bearings and belts on the tools, or an efficiency of 80%.

Some authorities attempt to express the actual horse-power lost in friction per 100-ft. length of shafting and per counter-shaft and per belt, but while figures of this kind would be useful if approximately correct even, your committee has been unable to check them closely enough to feel warranted in quoting them. As a rough guide in laying down shop power plants, it would appear that the horse-power of generating station required per man for railway shops will average about 0.4-HP. Table No. 1 gives a few examples from tests of the power required to drive typical railway shop tools, both for iron and wood working. The greater number of these results for metal-working tools were taken from tests at the Baldwin Locomotive Works, and for wood-working tools from Pennsylvania R. R. tests.

TABLE I.—POWER REQUIRED FOR MACHINE TOOLS.

Tool	Nature of Work	Horse-power Required: Empty	Light Load	Full Load	No. of Cutters	Remarks
70-in. wheel lathe	Wheel center	....	4.4	7.9	2	Light cut.
	32-in. wheel center	....	4.7	5.8	2	⅛-in. deep cut.
	56-in. wheel center	1.5	5.2	6.2	2	
Horizontal lathe	56-in. wheel center	....	4.3	7.1	1	⅛-in. deep cut.
Large double frame planer	Two frames	11.0	....	21.6	2	⅛-in. deep cut.
Slotter, 18-in. stroke	Frames	2.3	5.0	10.3	1	Heavy cut.
Slotter, 12-in. stroke	Wrought iron, 6 in. thick	1.5	2.1	6.5	1	
36-in. planer	Frames	3.4	4.2	7.4	1	
		3.4	....	11.3	2	
Drill press	1-in. drill, wrought iron	.97	1.94	2.9	1	
	1½-in. drill, wrought iron	.97	1.92	2.2	1	
	2¼-in. drill, wrought iron	.97	1.94	2.85	1	
Boiler-plate shears	⅝-in. plate steel	3.5	6.0	19.0	1	
Boiler-plate rolls	⅛ in. by 10 ft. 6 in. long steel	4.6	14.4	19.8	..	
Jib crane, 10 ton 10 h. p. motor	Lifting 10 tons	1.2	....	13.0	..	
	Lifting 7 tons	1.2	....	11.0	..	
Jib crane, 6 ton 8 h. p. motor	Lifting 6 tons	1.2	....	11.6	..	
Traveling crane, 5 ton	Lifting and carrying 4 tons	11.9	....	19.3	..	
Planer	Empty	3.4	....	....	..	
	1 tool	....	....	7.4	..	
	2 tools	....	....	14.0	..	
Shafting	Empty	15.0	....	....	..	
	6 planers	....	....	20.0	..	
	4 milling machines	....	....	26.0	..	
	2 lathes	....	....	30.0	..	
	1 buff wheel	....	....	34.0	..	
Planer and siding machine	6-in. oak flooring	8.0	....	32.0	..	Top and sides planed.
24-in planer	12-in. yellow pine	2.5	....	11.0	..	Top only.
Molding machine	6½ in. yellow pine carlin	1.5	....	8.5	..	4 sides.
Daniel 30-in. head planer	Oak tender end sill	3.7	....	8.8	..	Cut ⅞ in. off top.
3-spindle boring mill	Oak, 2-in. bitts	0.5	....	2.5	..	
Large tenoning machine	Oak end sills	3.0	....	7.0	..	3¼ in.x5-in.x10 in. cut.
Circular rip saw, 28 in. diam	Oak 9¼ in by ¼-in. cut	1.5	....	20.0	..	
Band saw blade, 1½ in. wide	Oak, 12 in. thick	1.5	....	6.0	..	

Suggestions Upon the Manner of Installing an Electric Transmission Plant.

Both direct and polyphase alternating current systems are applicable for shop use, and each system has its advocates among electrical engineers. For long-distance transmission, say one mile or more, alternating transmission is almost a necessity; for shorter distances, and in cases of isolated plants in compactly grouped railway shops, the direct current system can be employed without any practical disadvantages in waste of power in transmission lines.

Mechanically the induction type of alternating motor has great advantages in its simplicity and the absence of rubbing contacts. When it is said that probably 90% of all direct-current motor repairs are to commutators and brushes, the importance of this statement is clear. A

further advantage in the induction motor is the strong mechanical design of the revolving element. This is built up of heavy copper bars firmly bolted to a cast center. The direct-current motor, on the other hand, is a complicated assemblage of small wires, made additionally weak by the necessities of installation.

The disadvantages of the alternating-current motor are its high speed and the fact that it is essentially a constant speed machine. For driving line shafting, a constant speed motor is entirely satisfactory, but for independent tool driving a variable speed motor has unquestionable advantages. If the alternating system is to be adopted, it is important to specify that the motors shall be of the "induction" type, as this is the only variety which is at all applicable for shop uses.

A further element of importance in the alternating system is that of "frequency" or number of alternations of the current per minute. It is difficult to give a positive recommendation as to the proper frequency without qualifications. Realizing, however, the importance of standardizing apparatus, your committee venture to suggest the specifications of "3,000 alternations per minute" for adoption in railway shop plants. Alternating motors of this frequency are now in general use and have the very great advantage of fairly slow speed.

Direct-current generators are built for 125, 250 and 550 volts pressure, which, allowing for ordinary losses in lines, corresponds to motor pressures of 110, 220 and 500 volts respectively. The 220-volt direct-current motor is practically the standard for shop purposes, the 550-volt motor is used for railway purposes, but this pressure is undesirably high for shop use. Incandescent lamps may be obtained for 220-volt circuits, or the more common 110-volt lamp may be used on such circuits by connecting two of them in series. A 250-volt generator, together with 220-volt motors, are therefore recommended for shop plants. Alternating-current motors are wound for either 220 or 440, and for similar reasons to the above, the 220-volt system is recommended.

As between the direct connected and belted machines the relative advantgaes may be thus stated: The direct connected generator is more compact and more solid in construction, especially in small machines, due to the greater size of its parts. It is therefore more durable and somewhat more efficient on account of elimination of frictional losses in belting. The belted generator has an advantage of cheapness in first cost, due to its higher speed, which means more output for the same amount of material; and the further fact, often of importance, its ready applicability to existing engine plants. For generators of 75-HP. or less, the belted machine answers every practical purpose, but above this size the purchase of the direct-connected machine will be found an economy in all new plants.

In planning the installation of a transmission plant with small beginnings for running, say, one electric traveling crane, transfer table, turn-table outfit and a few portable tools, a 75 or 100-HP. belted generator will be found a convenient unit size. It may be installed by belting from counter-shaft at the main shop engine, but it is altogether better to provide a separate engine, for the reasons that the electric drive may be needed twenty-four hours in the day for special work (such as roundhouse turntable), and it makes a good emergency power plant for portions of the shops working overtime. It may be also used at nights to light the roundhouse and other buildings. When the transmission plant outgrows the capacity of this generator, it may still be used as a "spare" or for overtime work.

In laying out a complete system of electric transmission to displace engine and shafting transmission, careful attention should, of course, be given to selection of unit sizes. Little advice can be given offhand for such a case, as the determination of average and maximum loads is the basis of all calculations. In large plants, say of 500-HP. or over, there should be two, and possibly three, units of the direct-connected type and selected so that the engines shall run as far as possible at economical loads, and that one unit may be out of service for repairs.

Calculation of generator capacity required can be made approximately from published data on power required to run machine tools. It is usual to install motors having a considerably larger nominal capacity than figured requirements, so that generator capacity need never be as great as the added capacities of motors attached. In fact, the generator load in an ordinary shop seldom runs above 50% of that of the combined motor capacity, and in shops having a large motor load the effect on generator of running a traveling crane, a transfer table and turn-table need not be considered, as the momentary overload capacity of the machine will be ample to take of such requirements.

Rating of Generators.—Generators are sold with a guarantee to deliver their rated capacity, when driven at a certain speed, indefinitely, with a maximum temperature rise, due to electrical losses, of an amount supposed not to be injurious to insulation. This rise should not exceed 40° C. above the temperature of the surrounding air. They are also guaranteed to carry an overload of 25 to 50% for two hours, and short-period overloads of 100% without injurious heating. These guarantees have led to an objectionable but common practice of figuring the engine size on the overload capacities; that is, it is quite customary to couple a generator to an engine having its economical rated capacity equal to the 50% overload capacity of the generator. The consequence is that load is piled on the generator as long as the engine will pull it without seriously dropping off in speed, and an expensive generator is finally ruined for lack of the common-sense precaution which would be furnished by a properly adjusted engine unit.

Motors.—If the direct-current system be adopted, a wide range of selection in motor types is possible. For line-shafting, motors should be of the shunt type. For individual tool driving, the shunt motor is also in most common use; but the compound-wound variable speed motor is recommended as a desirable substitute. In fact, it is the belief of your committee that one of the great advantages of electric driving is in the possibility of simple speed regulaton for large tools, and the attention of the electrical companies should be called to the importance of filling this requirement in their line of standard motors.

Motors are preferably of "open" construction; that is, with the ends of field frame uncovered. Where exposed to the wet or to mechanical injury from articles falling into it, the closed type of motor may be employed, but this type is not desirable where it can be avoided on account of its lack of ventilation, which means overheating unless the motor is of relatively large size for the work to be done. For traveling cranes, hoists, transfer tables, locomotive turn-tables and boiler shop plate rolls, which start under load, run at variable speed, stop and reverse, the series-wound motor is the best, and is preferably of the enclosed style, which allows of more universal connection in any position, by gearing or otherwise, than the open type, and the question of heating is not so serious on account of intermittent running.

For alternating motors, the same considerations as for the "direct" apply; but, as elsewhere explained, variable speed running in this type for tool-driving motors is not practicable. For crane work, however, the induction motor is successfully applied by attaching special controlling devices.

In selecting motors, the importance of keeping down the number of sizes should be had in mind. This should be done at the expense of some increase in first cost and in spite of some waste of power due to reduced efficiency of underloaded motors, especially as their reliability is thereby enhanced. Competition among the makers of cheaper grades of motors has resulted in giving ratings dangerously close to the maximum safe working limit, and with all motors a reduction in the working load greatly increases their durability.

In deciding upon the make of motor to be purchased there is the same range for selection as found in other lines of machinery; but as an electric motor is a somewhat delicate machine, it is important to select only those made by reliable manufacturers. Such can be had of several companies, but they are not the lowest in first cost, and, in absence of definite information, it is generally safest to avoid very cheap machines. Even the best manufacturers make motors with different ratings as to speed and heating limits, and the lowest speed and lowest heating limit motors should be selected. This latter should not exceed 40° C. rise above external temperature at continuous full load run. The speed should be the so-called "slow-speed" variety. Table No. 2 gives about the proper speed for each of the standard sizes of shunt motors. It also gives the approximate selling prices of the list, based upon the highest grade machines; price includes motor, with pulley, base-frame and belt tightener, and starting box. A corresponding list of "medium-speed" motors may be obtained, the speed for a given power being about 50% higher than given in table, the prices being about 20% less on smaller and 35% less on larger sizes.

TABLE II.—Speed and Prices of Slow-Speed Direct-Current Multipolar Motors.

Rated output, HP.	Speed, R. P. M.	Price.	Price, per HP.
2	1,200	$135	$67
3½	1,050	190	55
5	950	240	48
7½	850	310	41
10	750	400	40
15	650	500	33
20	600	600	30
30	575	850	28
40	550	1,050	26
50	550	1,200	24

Manner of Tool Driving.—This varies in accordance with the motor arrangement and may be by (A) the group system; (B) the individual system. The selection of one or the other system depends upon the size of the tools and the consideration of intermittent or continuous running. In general, where the tools require less than 3 HP. each, it is best to drive them in groups from short-line shafts, which, as a rule, should not require more than 25 HP. per shaft group. Where,however, 3 HP. or over is required, or where variable speed or intermittent running is desirable, each tool should have its own motor.

In the group system the motor may be either belted to or direct-connected on the end of the line shaft, accordingly as space or plant cost permits. In individual driving either belted or geared motors are employed. The arrangement is somewhat clumsy, but reduces shock and prolongs the life of the motor, and is, in the opinion of your committee, the better arrangement for general use.

Conclusions.

1. In a small shop, consisting of practically one building, having an equipment of small tools for light work only, electric transmission will not be found a paying investment. In such a shop, however, an electric lighting dynamo will be a convenience, and may be utilized to run a few labor-saving electric tools, such as a cylinder boring outfit, a turn-table motor, etc.

2. In an extensive railway shop plant the installation of a central power station and electric transmission will always be found advisable, as it will not only result in the most economical system in respect to operation, but will make possible far more important shop economies, namely, an increase in quantity and quality of output and a reduction in cost of handling the same.

Appendix.—Examples of Electric Shop Power Plants.

Westinghouse Aair-Brake Co.—This large plant consists of a compact group of buildings, and is devoted to the manufacture of light apparatus by means of tools, each of which requires but a small amount of power, the manufacturing being conducted by a symmetrical arrangement of group-driven tools from line shafting.

The original power equipment consisted of central boiler plant of 2,000 HP., which furnished steam for heating and lighting, and to run air pumps, and 30 Westinghouse compound steam engines of 5 to 200 HP., placed in various departments and used to drive the line shafting. Although this system was well planned of its kind, the length of steam piping was necessarily considerable and the losses from condensation heavy. The great increase in business eventually overtaxed its capacity—especially in the matter of boiler power—and it was figured that the necessary relief for the boilers could be obtained through the superior economy of electric transmission. This was introduced under circumstances which make comparisons instructive, 23 of the separate engines being replaced by three large condensing ones (Parson's steam turbines) of 400 HP. each. These were placed in the engine-room adjoining the boilers, and each was direct-connected to a three-phase alternating generator running at 3,600 revolutions.

The power was thence distributed to 56 induction motors throughout the works. These motors have an aggregate nominal capacity of 1,050 HP., of which two, aggregating 250 HP., are used for pumps, etc., in the power-house, leaving 800 HP. for shop power, as against 1,300 nominal HP. of the 23 engines displaced.

The manner of connecting the motors is for group-driving of tools from sections of line-shafting, by belting to the motors placed on ceiling timbers or other convenient places. The original shaft sections were about 400 ft. long, driven by an engine belted to the middle of the length; for electric driving, these sections are split up into four, with a motor for each. The motors are generally of 15 HP. capacity, and drive the shaft sections at the most suitable speeds for the groups of tools connected. The shaft speeds were increased some 10% under the new arrangement, and range from 110 to 170 revolutions per minute.

Thorough arrangements were made for comparative tests of results under the two systems of driving, this being accomplished by retaining temporarily all of the original steam engine plant and converting the system from one method of driving to the other during the testing period. Details of the test results cannot be given in this place, but the general conclusions are interesting. These show a saving for electric driving during eleven and one-half hours' day run of 33% of fuel consumed and about 40% in amount of water evaporated. This fuel saving represents the commercial economy of the new system, and results from several causes, namely, reduced shafting losses, superior economy of large condensing steam turbines over that of the small non-condensing steam engines, elimination of condensation losses in steam piping, and better evaporation results from the boiler plant because of the less forcing of the fires.

Chicago Great Western Ry.—The new shops of this company at Oelwein, Ia., were planned for electric driving throughout, the system being of the 220-volt direct-current type, with group-driven machine shop tools. The exhaust-steam method of heating is employed, using two fans, each driven by a 25-HP. motor. An electrically-driven transfer table furnishes means for all transferring operations, large and small, the shops being specially arranged to be served from this one table, which travels at a speed of 200 to 400 ft. per minute. The electrical energy needed in winter, including power required to drive the heating fans, is as follows:

Average electrical horse-power, without lights	325
Maximum electrical horse-power, with lights	450
Night load	65
Nominal motor capacity, horse-power	450
Nominal generator capacity, horse-power	525

The generating station is arranged with three equal units of 150 HP., an unusually liberal amount of power for the capacity of the motors connected—a fact in part accounted for by the large percentage of power used to run the heating fans and for the lighting.

General Electric Co.—The enormous plant of this com-

pany, at Schenectady, is, as would be naturally supposed, equipped for electric driving, and represents the latest ideas. Small and medium size tools are in general driven by the group plan, the short lines of shafting being run by variable-speed motors mounted directly on the ends of the shafts, constituting a novel plan of driving without belting or gears, while large tools are driven by individual motors attached direct or by gearing. A noticeable feature is the use of portable or shifting tools for very large work. These tools are provided with geared motors, the tool being moved to the work, instead of the work to the tool. This method is especially applicable for the machining of very heavy and bulky product, but may be used to advantage for special light tools in railway shops, as is pointed out elsewhere. The entire shops are served by the indispensable electric power crane. These are, in the larger sizes, provided with auxiliary hoists operating at fast lifting speeds for light work.

The motors are of the direct-current variable-speed type, and the speed is regulated by a combination of two methods, as follows: The distribution is on the "three-wire" system, the two outside wires having a voltage of 250 between them, while the middle wire carries a potential difference of 125 volts from the other two. The motors are wound for 250 volts, and are connected between the outside wires to run at a certain standard speed; for a lower speed the connections are switched to one outside and one intermediate wire, operating, therefore, at one-half voltage. From this lowest speed to the normal one at 250 volts a gradual speed rise is effected by weakening the magnet strength of the motor field; and, on the 250-volt connections, the motor is further speeded up by again weakening the field. It is seen that these valuable properties of wide speed range are obtained in a very simple manner.

Examples of the speed variation possible in these motors are:

4½	-HP.	motor	runs	at	400	to	800	revs.	per minute.
7	"	"	"	"	250	"	500	"	"	"
12½	"	"	"	"	150	"	300	"	"	"
15	"	"	"	"	130	"	260	"	"	"

Baldwin Locomotive Works.—These works illustrate one of the earliest as well as probably the most extensive examples of electric machine shop driving. It is not too much to say that their manufacturing methods to-day hinge largely upon changes made possible by the use of electric power, and that no other agency could be substituted wholly therefor except at incomparably greater expense in space, installation and maintenance. In these immense works, situated in the heart of a large city and employing 8,000 men, the fullest utilization of space and the utmost simplicity and rapidity of handling operations are essential, and many ingenious examples of the convenience and economy of electric driving are here to be seen.

The electric plant is of the 250-volt direct-current type, the generators being direct-connected and aggregating 1,550 HP. normal capacity. The motors are almost exclusively of the multipolar belted type, and number 320, having a total rated capacity of 3,500 HP. Only about 5% of these motors are of the "series" type—an unusual condition, and due to the fact that the cranes are equipped with shunt motors.

About 950 HP. at the powerhouse switchboard is required on an average to run the entire power plant, and this figure is fairly constant throughout the day.

Electricity was first introduced in the erecting shop for driving two 100-ton traveling cranes, and an immediate saving of eighty men in the laboring force was thereby effected. The possibility of this result is seen when it is noted that a crane is capable of lifting an entire locomotive, or the parts of same, thus allowing the erection of a large number of locomotives to be carried on in a contracted space and without interference or delays connected with manual handling operations. Hand-drilling operations were also largely reduced in this department by substituting electric portable drills.

In the wheel shop large economies resulted from electric driving. By remodeling the shop the overhead shafting was done away with, each lathe being equipped with a separate motor. The two long main aisles formerly necessary for handling the work in and out of the machines were utilized for additional lathes, giving about one-third more machines in the same floor space; and the shop was served by an overhead traveling crane, instead of the hand jib-cranes in former use. The result was a reduction of common labor force from forty men down to six, and a reduction of the time consumed in reloading a lathe from thirty to five minutes. The saving in power for this shop was also considerable, estimated at fully 50%.

Similar results followed the introduction of electric driving in the frame shop, where the cutting out of overhead shafting and the use of traveling cranes enabled them to cut down the laboring force 60%.

In all the above cases the use of cranes was made possible only by the electric driving of the tools to be served by them.

The motors are, in general, connected to large individual tools by belting from a self-contained counter-shaft and speed-changing drive mounted on a frame connected with the tool. Group-driving is employed for small tools from short-line shafts.

The cranes are of the single-motor type, having a shunt motor belted to a train of gearing and clutches. This type of crane is highly thought of in these works and is considered superior to the three-motor type in its smoothness of action, ease and accuracy of handling and reliability. It is, however, higher in first cost than the latter type.

The cost of electric power at these works has been estimated at about $1,200 per week, which sum includes cost of fuel, engineers and firemen, labor and material for repairs of powerhouse, lines and motors. It also includes interest and depreciation on first cost of plant. It is interesting to note that this entire amount is about 1.2% of the shop pay-roll.

THE TOPOGRAPHY OF THE NICARAGUA CANAL ROUTE, AND THE PLANS AND ESTIMATED COST OF CONSTRUCTING THE CANAL.

By E. S. Wheeler, M. Am. Soc. C. E.*

(With single-page plate.)

The report of the Nicaragua Canal Commission of 1897-9 contains 500 pages of text and a volume of 40 maps. This size was necessary in order to present properly the new data collected by the commission. It is thought that the principal results expressed in a few pages without data or discussion would prove interesting to the general reader. The following article has been prepared with this in view. It contains nothing not given in the report of the Chief Engineer to the Commission, but an attempt has been made to present its results and conclusions in a briefer manner, with only a reference to the data and discussions which are given in the report.

A clear understanding of the topography of the canal region is of the first importance. For this purpose the accompanying map has been made, designed especially to illustrate and emphasize the topographical features of the region. Along the line of the location there is a belt of several miles in width, where the topographical data is very accurate and minute, being the aggregate results of many canal surveys. In more distant parts it is not nearly so minute. The elevations of mountain peaks are taken from the latest and best sources, and the map here given is as accurate as existing data will permit.

The general plan of the topography is very simple; it is geologically recent, and is therefore very clear. There are three principal mountain ranges, shown conspicuously on the map. The first in point of size is the Costa Rican Mountains, having peaks 10,000 and 11,000 ft. high; the second, the Nicaraguan highlands, having peaks 5,000 to 7,000 ft. in height, this latter elevation not shown on the map, and the third the West Coast volcanoes, having peaks 6,000 ft. high. These three elevated ranges are the governing features in the topography, all others being secondary and resulting from these three primary ones. A reference to the map will show the relative size and position of these three ranges.

The area of the map is limited, so that only the northwestern part of the Costa Rican range and the southeastern parts of the Nicarguan highlands and West Coast volcanoes are shown. It will be seen that the Costa Rican mountains and the Nicaraguan highlands overlap each other for about a hundred miles, their crest lines being parallel to each other, and about 70 miles apart. Between them lie the San Juan valley and river.

The West Coast volcanoes lie between the Nicarguan highlands and the line of the Costa Rican mountains. All have a northwesterly and southeasterly trend which is a characteristic of Central America, as has been pointed out by Dr. Hayes in his report to the commission, and by Mr. Robert T. Hill in his geological history of the Isthmus; other characteristic features are as follows:

The map shows that the Costa Rican mountains are higher and more massive than the Nicaraguan highlands. They are of more recent formation. They are of volcanic origin; some of the craters are still smoking. The rock of which they are composed is dark and coarse-grained, quite friable and easily disintegrated into a coarse black sand. The immense rainfall on the slopes of these mountains make many torrential streams which wear deep gullies and ravines. This black sand is readily carried along in the stream; it is too heavy to be carried in suspension, but rolls along the bottom, making a stream of sand almost as uniform as the stream of water above it. Some interesting measurements of these sand streams in the San Carlos and Sarapiqui were made by Mr. A. P. Davis and reported to the commission. All of the streams having their sources in these mountains carry this sand to the sea in such quantities that the entire sea shore is bordered with it from Port Limon to Greytown, and still farther north. This sand movement is mentioned specially because it is an important factor in the canalization of the San Juan River and the construction of a harbor at Greytown.

The Nicaraguan range has elevations of from 5,000 to 7,000 ft. in the northern part of Nicaragua, but steadily and quite uniformly diminishing in altitude to the southeast, until, as shown by the map, it finally disappears in the delta of the San Juan. This region, which is hardly high enough to be called a mountain range, has been termed the highlands of Nicaragua so as to distinguish it from the mountains of Costa Rica. It is of volcanic origin, but much older than the mountains of Costa Rica. It has been worn and channeled by streams until its surface is an assemblage of irregular hills, all of which are thickly wooded to the top. The numerous streams carry but little sediment, which is mostly yellow clay in suspension.

It will be observed that the crest line at the southern extremity approaches quite close to the San Juan River, so that from the junction of the San Carlos to the sea the San Juan has no large tributaries from the northern side. This is an important feature in the location of the canal.

The West Coast volcanoes form a line of isolated peaks beginning with Ometepe in Lake Nicaragua and ending with Coseguina on the gulf of Fonseca. This latter is not shown on the map; it is about 40 miles farther to the northwest, making the total length of the range about 180 miles. Before they were in existence the shore of the ocean was approximately as shown by the dotted line, which is not complete on the map, but terminates about 25 miles farther to the northwest at the head of the Gulf of Fonseca. The volcanoes must have broken out in the bottom of the sea, and by their outflow built up and added to the continent all that area which is surrounded by the dotted line. The map shows that before the formation of these volcanoes the area which is now Lake Nicaragua was a bay behind a long point projecting into the Pacific Ocean to the northwest. The outflow from the volcanoes built out the shore until it connected with and covered the northwesterly end of this point and thus changed the bay into the present lake. A portion of the southeasterly end or the base of this point had been covered and built up by the flow from the Costa Rican mountains, but the two flows did not quite join each other. The canal location is found between them and in the earlier stratified rock.

Some of these volcanoes reach an elevation of nearly 6,000 ft. Many of them are still smoking. The volcano of Coseguina was in eruption in 1835, sending out a vast quantity of ashes. There have been no eruptions of any of them within the historic period that would have damaged a canal. The indications are that the period of great activity in these volcanoes is closed, and that the present is an era of subsidence. The earth tremors that are felt occasionally in the region are not the result of explosions, but are simply slight movements in the earth's crust as it settles and readjusts itself to its new conditions. It is believed that the line of the canal location is in no greater danger from earthquakes than any other sea coast region.

With this brief outline of the three primary and governing features in the topography of the canal region, we may consider some of the resulting secondary features.

It has already been mentioned that the Nicaraguan highlands and the Costa Rican mountains overlap each other for about 100 miles, and that between them lies the valley of the San Juan. This valley is limited at one end by Lake Nicaragua, and at the other by the Caribbean Sea. It is about 80 miles long, and between the foothills of the two ranges of mountains, about 25 miles wide. The

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map shows emphatically that it is not a break or low pass through a mountain range, but a region or valley lying between two distinct and widely-different mountain ranges.

With respect to a canal, this valley is of supreme importance, because it is through its lowest part that the canal must be built, if built at all. It is shown by the map to be intersected and channeled by many streams and dotted by occasional hills, so that at first the general plan of its topography is confused and concealed. If, however, we will suppose these stream valleys to be refilled with soil to the top of their banks as they originally were, there would then be reproduced a gently-sloping but even and uniform plain, with occasional low scattered hills. A longitudinal section of this plain through its lowest part would show a very uniform rise from the Caribbean Sea up to the neighborhood of Castillo; here the surface of the plain would be about 200 ft. above the sea level. It would then gently decline towards Lake Nicaragua, where it would have an elevation of about 100 ft. In the highest part, in the vicinity of Castillo, the hills would be thickest, yet nowhere connected with each other so as to form ridges. The highest of these hills is the one in the angle formed by the San Carlos and San Juan rivers, which rises about 900 ft. above the surrounding plain, or 1,100 ft. above sea level.

A transverse section of this valley at any point would show the plain rising in either direction from the lowest part at the rate of about 4 ft. per mile, sufficient to make a swift current in the streams, but no cataracts or falls until the foothills on either side are reached.

The salient features of the topography of this valley are then: First, a gently undulating plain; second, stream valleys through it; and third, occasional hills scattered about it. If a modeler were to make a map of this valley in relief he would probably first make the undulating plain, sloping down from the foothills on either side to the lowest part at the rate of about 4 ft. per mile; also sloping from the vicinity of Castillo in both directions to the lake and sea at the rate of about 1½ ft. per mile; next he would cut in the plain the stream channels exactly as the streams themselves had done; lastly, he would build up on this plain the scattered hills in their proper places. The lowest part of the plain is much nearer the Nicaraguan highlands than it is to the Costa Rican mountains. The stream valleys are widened at their lower ends so that in many cases they join each other or are separated only by narrow ridges. The San Juan River has cut its channel or gorge through the crest of this plain. In the central or higher part the gorge is more than 100 ft. deep. The shaded parts of the map lie below the 150-ft. contour lines. If the ocean should rise 150 ft. it would flow clear across the continent, and its shore line would then be the same as the boundaries of the shaded areas on the map. It will be noticed that this shaded area through which the San Juan runs is very narrow for several miles showing that the river is flowing through a gorge with elevated plains on both sides.

Since these plains have an elevation in their central parts of at least 200 ft., and the elevation of Lake Nicaragua is 105 ft., it follows that a canal having Lake Nicaragua for its summit level must pass through the gorge of the San Juan River, otherwise an artificial cut of fifty miles in length, and depths of more than 100 ft. would be necessary. Since such a cut is out of the question the inference is simple and certain that the canal must be located in the gorge of the San Juan for at least 60 miles. This conclusion, though not hitherto distinctly enunciated, has been tacitly recognized in all previous canal surveys, since no other location between Lake Nicaragua and San Carlos River has ever been suggested.

The area in which a canal is feasible is thus confined to very narrow limits, and the problem of location is greatly simplified.

The southeastern end of the San Juan valley is largely filled by the delta of the San Juan River. On the map the delta is shown by the darker area. Perhaps the upper part might be more correctly called the flood plain of the San Juan, but it is not possible to say definitely where the flood plain ends and the delta begins. The two plains are so similar in their characteristics that for the present purpose they will be considered together. This plain has a seaward slope of 1½ ft. per mile, its surface is covered with a dense forest growth of a swampy character. During the wet season large portions of it are covered with several feet of water, and it is then impassable except in canoes.

The material, in the upper portions, is a yellow clay similar to that covering the Nicaragua hills. Along the seaward edge there is a belt of black sand extending inland in some places two or three miles. There are many old water courses and lagoons filled to a considerable depth with decaying vegetation.

The entire plain is very uniform. Four different canal routes were run across it and the estimated cost per mile was nearly the same in all of them. It thus happens that where there is considerable width in the feasible canal area there is not much choice in location, all being approximately alike, at least so far as actual cost per mile is concerned.

On the west, the valley of the Rio Grande and the Lajas is so much lower than any other pass between Lake Nicaragua and the Pacific that it alone need be considered in connection with a canal.

It has already been pointed out that this valley lies between the volcanic outflow from the Costa Rican mountains, and the more recent outflow from the west coast volcanoes. The rock is largely sandstone and shale. The surface of the land has been deeply channeled by stream erosion, so that now it resembles an irregular assemblage of hills. It may be said of the valley of the Rio Grande and Las Lajas, as has been said of the gorge of the San Juan, that if a canal is built at all it must be through this valley. This conclusion has also been tacitly recognized in all preceding canal surveys, since no other location between Lake Nicaragua and the Pacific has ever been recommended.

It will be noticed that the shaded area on the map, or the 150-ft. contours, pass clear through this valley from Lake Nicaragua to the Pacific. At no other place do these contours approach within several miles of each other.

A significant feature of this pass is that it was formerly the outlet of Lake Nicaragua. That the outlet should at one time have been westward to the Pacific, and then should change and go eastward to the Caribbean Sea can be readily understood. When the lake was first closed off from the sea it rose until it found an outlet. At that time the gorge in the San Juan valley had not been completed, and the streams ran from the vicinity of Castillo both ways, eastward to the Caribbean and westward to the Pacific. Under these conditions the first outlet that the lake found was westward; in time the streams having their sources near Castillo work d back and completed the gorge through the continental divide so that the outlet of the lake was turned eastward. For a short time at least the lake had two outlets, but the eastern one, being in clay, cut down more rapidly than the western one, which was in rock. So in a short time the lake was lowered below the western outlet, and the eastern one had captured the entire outflow. At the present time the lake is about 50 ft. lower than its former western outlet. The flow to the westward must have been of long duration, for there remains a gorge cut in the solid rock 20 to 40 ft. deep and three or four miles in length. The canal has been located so as to utilize this gorge, and the required amount of rock excavation has been correspondingly diminished.

Lake Nicaragua is an important factor in the topography of the region. Its salient points are shown on the map. Its area at a mean stage is 3,000 square miles. Its greatest depth found is 200 ft.

From the preceding the reasons for the final choice of location will be readily understood. It has been shown that the canal location on the west side must be in the valley of the Rio Grande and Las Lajas, and on the east side between Lake Nicaragua and the San Carlos, it must be in the gorge of the San Juan.

The first and most important question to be answered is, whether or not the gorge of the San Juan can be utilized for a canal with the river San Juan still flowing through it, and it is one that has never been adequately discussed.

The reason for this seems to be that the early canal engineers assumed the maximum flow in the San Juan, where it leaves Lake Nicaragua, to be 18,000 cu. ft. of water per second, "and not very much increased by its tributaries until it reaches the San Carlos." Such a discharge as this would make a maximum velocity less than 2 ft. per second, which would not interfere with the safe passage of ships; therefore it was considered that the gorge could be used for the canal and the river simultaneously.

The Canal Board of 1895 was the first to point out that this maximum flow was greatly underestimated. With the scanty data then available the board doubled the former estimate, making the probable maximum amount flowing from Lake Nicaraugua 36,000 cu. ft. per second, with the possibility that it might reach 50,000. The difficulty of navigating the river under these new conditions was pointed out, and, as a remedy, it was suggested that an increased width be made in the artificial channel.

The results obtained by the commission of 1897-99 show that the discharge from Lake Nicaragua often reaches 50,000 cu. ft. per second. The drainage into the San Juan above the San Carlos also reaches 50,000 cu. ft. per second, so that the discharge of the San Juan above the San Carlos often reaches 100,000 cu. ft. per second, and there is conclusive evidence that floods greater than this have occurred.

It was also found that such floods would make a velocity in portions of the canalized river of more than 6 ft. per second. It is believed this would make navigation impossible for the time being and would also erode the banks and fill up the artificial channels, so that the canal would not be usable after the subsidence of the flood until portions were re-excavated.

These flood conditions are so vastly different from those hitherto supposed to exist, that the question of the possible canalization of the river must be reconsidered in the light of the later data. This has been fully discussed in the report of the Chief Engineer to the Commission. Only the results will be given here, which are as follows:

If such floods are uncontrollable the gorge of the upper San Juan can not be used for a canal. With a flow of only 18,000 cu. ft. the river could be canalized, but with 100,000 it cannot. The means for controlling these floods are three: (1) By dams and wasteways in the San Juan River which will temporarily retain the water in Lake Nicaragua and allow it to flow out at a limited rate; (2) by enlarging the cross-section in the San Juan River until its flood velocity ceases to be injurious; (3) by the creation of a new wasteway on the Pacific side, and thus withdrawing the larger portion of the flood from the San Juan River.

Any one of these methods, if employed alone, would involve a cost that would be practically prohibitive. The minimum cost is found by a judicious combination of the three. It has been found that a fluctuation of 6 ft. in Lake Nicaragua should be allowed in order to provide for the evaporation during long dry periods. Therefore, this 6 ft. can be used for storing water during the wet periods, and the first method can, therefore, be incidentally utilized to this extent. Again, it is believed that a width of river channel of at least 300 ft. is essential for the safe navigation of modern ships. Therefore the second method will be incidentally utilized to this extent. Finally, it is found that the canal on the west side can be utilized for a wasteway through its ten miles of rock cut, and, when necessary, can discharge 35,000 cu. ft. per second, without serious inconvenience to navigation. With these conditions it is found possible to reduce the maximum flow in any part of the San Juan to less than 30,000 cu. ft. per second, with a velocity less than 2 ft. per second, which it is believed will not seriously impede navigation or erode the channel banks. The question, therefore, as to whether the gorge of the upper San Juan can be used for a canal with these conditions may be answered in the affirmative.

The location has, therefore, been made in the gorge of the San Juan, as shown on the map. From

Brito on the west side to the mouth of the San Carlos on the east side, the location is confined by natural causes to very narrow limits, and it is safe to say that no location between these points will ever be seriously considered that differs essentially from the one here given.

From the mouth of the San Carlos to the sea there are wider possibilities. It was found impracticable to use the river below the junction of the San Carlos because of its great volume, the large amount of sediment carried, and the great depth to suitable foundations for dams.

It has been previously mentioned that no large streams flow into this reach of the river from the Nicaraguan side. This makes it possible to locate the canal in the narrow plain lying between the river and the Nicaraguan hills.

From the head of the delta to the sea several different routes were examined. All seemed about alike, and the one finally chosen is shown on the map.

As to the value of the entire location, it is believed to be very nearly as good as any that can be made, though it is quite probable that more minute surveys may suggest minor changes that will slightly lessen the cost; but it is not believed that any changes can be made that will diminish it as much as 10%.

With the location definitely fixed, the character of the canal and the methods of its construction may be considered. This part of the work is much more arbitrary than the selection of a location. There is in fact one location which is better than any other, and the engineer's duty is simply to find it, and to be able to convince others that he has found it. The best kind of canal, however, is a variable quantity. That which would have been best when the Nicaraguan Canal was first proposed would be useless now. It is only possible to select the best form for the present and the immediate future. A recent paper by Mr. Corthell on the probable future size of ships was a timely and valuable aid in this connection. Some of the principal dimensions for which all estimates of quantity and cost were made were as follows: Depth of canal, 30 ft. at lowest stages of sea, lake and ocean; width of canal, in earth sections, 150 ft., in rock section on west side, 200 ft., in river section 300 ft., in lake section from 300 to 600 ft. usable length of locks 620 ft., width of locks 80 ft., depth of locks 30 ft. These dimensions are slightly varied where necessary, as in the vicinity of harbors and curves. They are in the aggregate larger than any for which estimates have ever been made before.

The most desirable number of locks has been discussed with much care, estimates having been made of the cost of the canal with different systems of locks. On the east side, systems of 3, 4, 5, 6, 7 and 8 locks were estimated for. The total cost of the canal steadily diminished as the number of locks increased from three to six; it then began to increase, a system of eight locks costing more than one of six or seven. This is due to the fact that the cost of excavation diminishes with the number of locks, while the cost of lock construction increases with their number. A system of six locks was selected for the east side, and a system of four locks for the west side.

The fluctuations in the surface of Lake Nicaragua were carefully studied, the principal data being the single year's observation made by the commission, supplemented by a rainfall record of 20 years made by Dr. Flint, at Rivas.

It was found that during the last twenty years there had been several periods of 19 months each when the rainfall on the west coast did not exceed 2 ins. per month, and that during such periods Lake Nicaragua would fall 4½ ft., even without any outflow. It was, therefore, found necessary to allow for the storage of at least 4½ ft. of water in Lake Nicaragua to provide for these exceptionally dry periods; and, to provide a margin of safety, one foot and a-half was added to the storage, making 6 ft. of fluctuation permissible in the lake level. It was further found that the most convenient limits between which the lake surface could be controlled was elevation 104 and elevation 110 ft. The depth of the canal being 30 ft. at lowest stage of lake, it follows that the grade of the bottom of the canal throughout the summit level would be 74 ft. above sea level.

The question of the number of dams and their location in the San Juan River is of importance. The river has a fall of about 55 ft. from Lake Nicaragua to the mouth of the San Carlos. This fall must be controlled by dams. Estimates have been made of the cost of systems of one, two, three and four dams. It was found that the cost increased with the number, one high dam costing less than a system of two, three or any greater number; but it was deemed prudent not to permit the question of cost to govern entirely. One objection to a single dam is that it makes a very large artificial lake many square miles in extent, and the consequences of the failure of such a dam would be appalling, involving great destruction of life and property below it. A system of three dams with a fall of 18 ft. each would not cause the water to rise above the banks; the artificial pools would be small in area, and the impounded water not sufficient in volume to cause much damage in the event of the failure of a dam. Three dams increase the cost above one by $4,000,000. Again, a fall of 18 ft. corresponds to the lift in each lock in a system of six locks; for these reasons a system of three dams was chosen with locations at Boca San Carlos, Conchuda and Machuca.

The necessity for a wasteway to the Pacific has already been mentioned. Its plan and location are shown in the small map in the corner of the large one. It is proposed to take the water from Lake Nicaragua through the canal for ten miles This part of the canal will be a rock cut with vertical sides protected by wooden fenders, which it is believed will make navigation safe even with an occasional current of 5 ft. per second. Such a current cannot in the least injure the rock walls of the canal. The waste water will leave the cana above the first lock through a long series of valves in the side of the canal; it will then follow the bed of the Rio Grande, which will be enlarged and rectified as shown on the map.

This question of a wasteway to the Pacific has been more fully discussed in the report of the Chief Engineer, and is believed to be of supreme importance; for, unless some way is provided to relieve the San Juan from its occasional torrential floods, it is doubtful if it can be used for a canal, except intermittently and during periods of low water.

The location of the canal locks and dams is shown on the map, and it is seen that all locks on the east side are between Machuca and the sea, or in the first 60 miles of the canal; on the west side all locks are between Buen Retiro and the ocean, or in the last 7 miles of the canal. The summit level is between Machuca and Buen Retiro, and is about 120 miles long; and in all this part of the canal the water surface will be permitted to fluctuate 6 ft, so that if there is a depth in the canal at low water of 30 ft., then at high water there will be a depth of 36 ft.

There are three dams in the San Juan, one above the mouth of the San Carlos, having a fall of 18 ft., one at Conchuda, also having a fall of 18 ft., and one at Machuca having a fall varying from 18 to 24 ft., as the elevation of the water surface changes in the upper level. The Machuca dam will be provided with spillways, so that the flow from Lake Nicaragua can be regulated or closed entirely when necessary. It has already been mentioned that the drainage into the San Juan River between Lake Nicaragua and the San Carlos River is at times as much as 50,000 cu. ft. per second. At such times it is proposed so to regulate the spillways at the Machuca dam as to turn 25,000 cu. ft. per second back into Lake Nicaragua, and permit the remainder to pass down the river and over the dams at Conchuda and San Carlos. In this way the maximum flow in any part of the canalized river will be limited to 25,000 cu. ft. per second, and with the enlarged cross-section the maximum velocity will be less than 2 ft. per second. During dry periods the spillway at the Machuca dam will be closed entirely, and it is expected that such dry periods will at times continue for 19 months. At each dam there will be a lock as shown on the map.

On the west side, the first 10 miles of the canal will be through a rock cut; the greatest depth of which will be about 70 ft. It is through this cut, and the wasteway which is shown on the small map, that the drainage of Lake Nicaragua will be taken to the Pacific.

It is for the general plan outlined above that estimates of quantities were made, and the data for these estimates is quite full. The line of the location was cross-sectioned wherever the surface was at all uneven, but through a few miles of the delta plain of the San Juan only a single longitudinal section was determined. In this connection a line of precise levels was carried from the Caribbean Sea to the Pacific Ocean, and their difference in level determined. For the purpose of classifying the material, borings were taken along the line of the location at intervals of not more than 3,000 ft. in all critical places.

The character of the material varies in hardness from river silt to basalt, but the data is not sufficient to make a minute classification; it is, therefore, divided into two general classes, earth and rock, the former containing all that part which is soft enough to be excavated without the use of explosives, and the latter all that requires blasting. In many cases one class shades imperceptibly into the other, but the rule that was followed in boring was to call the material rock wherever it was hard enough to yield a core.

In addition to the canal proper there are required two artificial harbors, which present engineering problems quite distinct from the ordinary canal work. Their discussion is too long to be given here, but a bare outline of the conclusions will be given in order to complete the estimates.

At Greytown it is proposed to build two parallel jetties from the shore out to seven fathoms of water; the jetties to have a space of 600 ft. between them, which will be dredged so as to make a channel 30 ft. deep to the shore. Inside of the shore it will be widened into a harbor. The material for the jetties must be of the kind already successfully used for building harbors and sea walls on open coasts. It will be seen from the map that Greytown is on the edge of the delta of the San Juan River, and from data now extant it is known that the delta at this point is pushing seaward at the rate of about 75 ft. per year. The accretions are principally the black sand from the Costa Rican mountains, which has already been mentioned. It is assumed that if an addition to the jetties of 75 ft. be made annually their outer ends will be kept at the seven fathoms curve. The plans for the interior harbor are for canal purposes only. If the port should require more harbor facilities for private business it would be considered separately from the canal.

At Brito, the harbor is to be built on an open seacoast; here the shore appears to be permanent no change from the earliest maps being observed. It is true that the harbor is in the small delta of the Rio Grande, but it seems that the forces of the sea are such that the delta cannot be pushed seaward beyond the rocky points on either side. Since the shore is permanent it is proposed to protect the entrance to the canal by a breakwater and two short jetties, as shown in the small map. The interior harbor will be excavated from the alluvium of the delta and of a size sufficient for canal purposes only.

A summarization shows that the route chosen, together with these plans for canal and harbors, requires the excavation and removal of 123,000,000 cu. yds. of earth, and 30,000,000 cu. yds. of rock.

The quantities having been determined, the next step is to assign unit prices for labor and material, and the methods used in deriving these prices were as follows: The work was first compared with similar work in the United States, and an estimate made of what the cost would be here. Second, an estimate was made of the difference in cost between work in the United States and Nicaragua. The sum of these two gave the cost in Nicaragua.

It was found that the Chicago Drainage Canal furnished the most satisfactory comparison for excavation, the St. Mary's Falls Canal locks for lock building, and various harbor works on both sea coasts for jetty and pier building.

The average cost for excavating the Chicago Drainage Canal was 75 cts. per cubic yard for rock and 28 cts. for earth. The methods improved during the progress of the work, so that the cost

of the last was less than the average. Messrs. L. E. Cooley and Isham Randolph have expressed the opinion that if the work should be repeated, it could be done for 65 and 25 cts. respectively. These prices are therefore used as a basis.

The earth in the Nicaragua Canal is found to be of the same general character as that in the Chicago Canal; its proposed disposition along the banks of the canal is also practically the same. It is therefore concluded that if the Nicaragua Canal were located near Chicago, the average cost of its earth excavation would be 25 cts. per cu. yd. The sandstone on the west side can be excavated somewhat easier than the Chicago limestone, but the location of the spoil banks are not quite so favorable as in the Chicago work. These two opposite conditions are taken as equal, and it has, therefore, been concluded that it could be handled at Chicago for the same price as the Chicago rock. On the east side the rock is basalt and dacite. Both are somewhat harder to excavate than the Chicago limestone, and the dump piles are not so conveniently placed. For these reasons, it is estimated that the cost per yard will be increased 10 cts. Therefore it is concluded that if the Nicaragua Canal were located near Chicago the cost of rock excavation would be 75 cts. per cu. yd. on the east side and 65 cts. on the west side.

The cost of the locks was obtained by comparison with those at Sault Ste. Marie.* The material estimated for is concrete walls, steel gates, wooden floors and conduits; the strength and size of the parts were taken proportional to those of the Ste. Marie locks. The unit prices that have actually been paid at the Sault were then applied. It was found that the ten proposed locks, if built at the Sault, would cost about $14,000,000. These two items, excavation and lock building, together make more than 80% of the estimated cost of the canal. Their unit prices are, therefore, the important and governing ones.

The cost of the remaining items when determined in a similar manner for the United States aggregates $15,000,000, and the total estimated cost for a similar canal if built in the United States is $80,000,000. Up to this point the data is reasonably full and exact, and the conclusions cannot be much in error. It yet remains to assign the relative cost of work in the United States and Nicaragua. This will involve greater uncertainty for the reason that there have been no large works in Central America with which comparisons can be made except the Panama Canal, and for obvious reasons comparison with this work would be misleading.

There has, however, been railway building in all of the Central American states, often in amounts so large that the entire labor was brought to the country from the outside, thus making the conditions of labor somewhat similar to those which would obtain if the Nicaragua Canal should be built.

*A discussion of the cost of the locks at Sault Ste. Marie, Mich., was given in Engineering News of June 1, 1893.

An analysis of the cost of many of these roads has been obtained from the engineers who built them. The range in results was quite wide, but all fell between 25 and 100% in excess of similar work in the United States. The excess in the cost of labor seemed to be more than for material. Different percentages were, therefore, assigned to different parts of the work, the weighted mean of all being about 65%; that is, it was concluded that the canal would cost 65% more in Nicaragua than in the United States. With the various percentages assigned to different parts of the work, the following estimate of the cost in Nicaragua is prepared:

East Side.

Excavation, earth, 106,441,923 cu.yds. at 37 cts.	$39,383,511
Excavation, rock, 6,158,160 cu. yds. at 93 cts..	5,727,088
Clearing 4,100 acres at $75 an acre.....	307,500
Clearing and grubbing 1,575 acres at $100....	157,500
Dam mas'ry, concrete, 385,529 cu.yds. at $8.30	3,199,890
Dam construction, not masonry	3,395,430
Four locks, lift, 18.4 ft.; depth, 48.4 ft.....	6,406,400
Two locks, lift, 18.4 ft.; depth, 53.4 ft.....	3,414,800
Waste-weirs	450,300
Sheet-piling, 1,059,800 ft. B.M., at $60 per M.	63,588
Breakwater, 550,000 cu. yds. at $1.75.....	962,500
Stone pitching, 120,000 sq. yds., at $2.....	240,000
Guard gate	172,000
Cribs, retaining walls	1,000,000
Railroad, complete Greytown to Sabalos River	2,701,110
Total Eastern Division	$67,581,617

West Side.

Excavation, earth, 16,226,281 cu.yds. at 31 cts.	$5,030,147
Excavation, rock, 23,099,488 cu. yds. at 81 cts.	18,710,585
Four locks, lift, 29 ft., at $1,853,145 each....	7,412,580
Guard gate	153,000
Waste-weirs	1,102,300
Timber pier, lake, 151,000 cu. yds. at $3.08..	465,080
Jetties, Brito harbor, stone, 144,107 yds. at $1.50	216,160
Clearing and grubbing, 661 acres at $100.....	66,100
Clearing, 1,127 acres at $75	84,525
Railroad complete	514,942
Total Western Division	$33,755,419

Summary.

Total Western Division	$33,755,419
Total Eastern Division.....	67,581,617
Total	$101,337,036
Sanitary and police	1,000,000
Light and buoys	500,000
Total	$102,837,036
Superintencence and engineering, add 6%....	6,170,222
Total	$109,007,258
Contingencies, add 20%.....	21,801,450
Grand total	$130,808,709

The largest source of error in this estimate is the ratio of cost between the United States and Nicaragua, but some limits to this uncertain

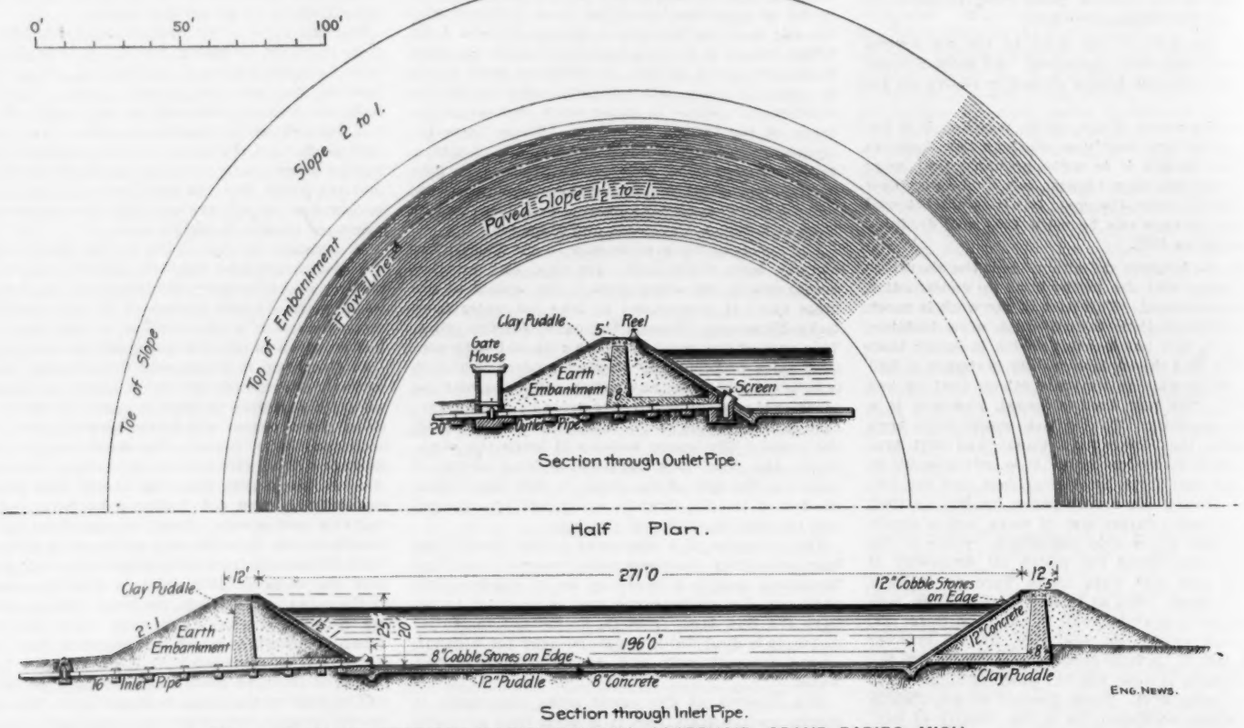

FIG. 1.—PLAN AND SECTIONS OF DISTRIBUTING RESERVOIR, GRAND RAPIDS, MICH.

The commission proposes (1) a single high dam in the San Juan River instead of three low ones; (2) to permit 85,000 cu. ft. of water per second to flow through the canalized portions of the San Juan instead of limiting it to 25,000; (3) to limit the flow westward to the Pacific to 15,000 cu. ft. per second instead of increasing the capacity of the wasteway to 35,000 cu. ft. per second. In addition to these points of difference, the unit prices here given and the methods of obtaining them are not fully approved by the commission.

Confidence in the results will be enhanced by the names of the men who collected and discussed the data. Mr. H. C. Miller was Frst Assistant Engineer. Dr. Hayes, of the Geological Survey, had charge of the geology. Mr. A. P. Davis, also from the Geological Survey, had charge of the hydrology and meteorology. Mr. J. W. G. Walker did the

topographical work, and made the location on the west side. Mr. F. L. Stuart made the survey of Lake Nicaragua and a portion of the San Juan River. Messrs. H. H. Trundle, Boyd Ehle, Andrew Onderdonk, S. S. Evans and L. Hankins made the surveys and locations on the east side. Mr. Stephen Harris did the precise level work. In addition there were 72 trained assistants and observers taken from the United States. About nine months were spent in the field work.

THE FAILURE OF THE DISTRIBUTING RESERVOIR OF THE WATER-WORKS OF GRAND RAPIDS, MICH.

A 6,000,000-gallon reservoir, forming a part of the city water-works of Grand Rapids, Mich., failed on July 2, as noted briefly in our issue of July 5. A correspondent in Grand Rapids has sent us an account of the failure, accompanied by a blue print and photographs. He believes that the failure was due to overfilling the reservoir. A second correspondent in Grand Rapids, Mr. L. W. Goddard, corroborates this view of the cause of the failure in a letter to this journal, dated July 5, as follows:

> There is little to be said of the cause of the failure beyond the fact that the reservoir was pumped full to overflowing (ran over in more than one place) and the bank, being of sand, with no protection of sod, was soon cut away and the concrete lining was broken.

The more detailed account of the failure, sent on July 6 by our other correspondent, is as follows:

> The failure of the reservoir at Grand Rapids, Mich., has been investigated sufficiently to ascertain the probable cause, though there was no witness of the first escape of the water which deluged the valley below the site of the basin.
>
> Evidence which has been collected by those desirous of securing the payment of damages caused by the break all goes to show that the disaster was due to no break in the walls or lining below the flow line, though the washing away of the banks may have been assisted by the weakened condition of the walls due to seepage. While investgation has not disclosed as yet the facts regarding the direct cause of the disaster, it has fixed upon the one fact that more water was pumped into the reservoir on the night of the break than the basin was intended to hold.
>
> The break occurred at the point in the south wall through which the only outlet pipe, a 20-in. cast-iron main, was carried. The pipe was undermined so that two sections of it fell below its level, and rested on the sand upon which the reservoir was built. At that point the entire clay puddle, which formed the core of the embankment, was washed out. A break 110 ft. wide at the top of the embankment, 25 ft. at the middle elevation, and 15 ft. at the lowest point was left when the water had escaped, leaving a depth of 4 ft. remaining. The lining of large cobblestone, set in concrete 2 ft. in thickness, was broken away in much smaller sections than the earth embankment and puddle core, as the photographs, taken immediately after the break, show. Approximately 1,700 cu. yds. of the embankment and walls were carried out by the flood, which was only a short time in tearing that amount away.
>
> The reservoir is situated upon the level crest of steep sand hills, at an elevation of 150 ft., at the normal flow line, above the pumping station, which is located one-half mile away on the banks of Grand River, the source of supply. Water was forced into the basin through one pipe of 16 ins. diameter. No watchman was maintained at the reservoir, but a daily inspection was usual. The height of the water was registered at the station by means of two gages of the usual spring pattern. There was no mercury gage. It was customary to maintain a pressure of 40 lbs. during the day, and at night the maximum pressure was 68 lbs., which was supposed to maintain the water at a level entirely within the safe limit of the reservoir. At the time of the discovery of the break, 4:45 a. m., it is claimed that the gages registered from 64 to 68 lbs., and had not been higher at any time during the night run of the pumps. The first notification at the pumping station that a break had occurred was after all the damage was done. A theory that the gages failed to correctly record the pressure through being out of order has not been substantiated. Until the board of public works concludes the investigation now being quietly carried out no blame can be attached to the men in charge of the pumps at the time of the supposed overflow. Two boys who discovered the escape of the water and alarmed those in its probable path say that the break in the top of the embankment appeared to them to be at least 5 ft. in depth.
>
> On account of the rapid giving way of the wall of the reservoir the water was released in such a flood as to do considerable damage. Houses were swept down the hillside to the east of the reservoir, streets washed out, and earth deposited against the sides and in the basements of many houses. One life only was lost as an indirect result of the disaster, timely warning having averted other fatalities. A conservative estimate of the amount needed to repair the damage to property and to public streets is placed at $50,000. The cost of repairs on the reservoir walls will depend on the extent to which it is thought necessary to go in strengthening the whole structure. At present only ample repairs of the breach are contemplated.
>
> As a peculiar circumstance, considering the probable cause of the difficulty, it may be noted that no overflow outlet of any kind existed. During the 25 years that the reservoir had been used no serious leak or overflow had occurred; with the exception of a good-sized washout due to a break in the force main.
>
> Mr. Samuel M. Gray, M. Am. Soc. C. E., was called to offer his opinion on the best method of repairs. In his statement to the water board he advocated the construction of an overflow, and also the use of additional and more reliable means of gaging the contents of the basin. A formal report will be made later.
>
> The water board has been criticised for its conduct of affairs. The city will probably adjust the claims for damages without litigation, a committee being now engaged in estimating the loss. Repairs are now under way and will be pushed as rapidly as may be.

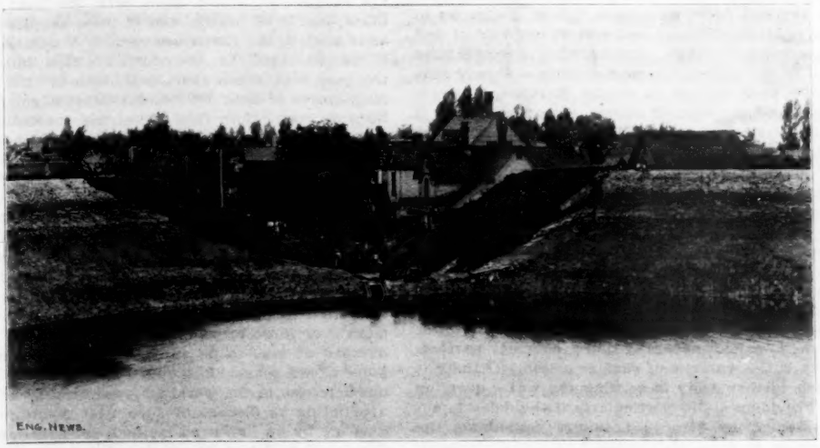

FIG. 2.—GENERAL VIEW OF BREAK IN RESERVOIR EMBANKMENT AT GRAND RAPIDS, MICH.

The reservoir was built in 1874 and put in use the latter part of the year, or early in 1875, with the other parts of the plant. The designing engineer was the late Mr. Peter Hogan, of Albany, N. Y. Mr. E. W. Muenscher, then city engineer, was constructing engineer. Messrs. Thaddeus C. Brooks and Alfred C. Sekell were the contractors for the reservoir, which cost about $55,500. Local reports state that the contract was not let until July 12, but was finished before cold weather.

The general design of the reservoir is shown by the plan and sections, Fig. 1, while the break is shown by the two views, taken three hours after it occurred.

Since the preceding was put in type our correspondent has written us that the water board has discharged the engineer who was on duty at the time of the break, basing its action upon an affidavit made by a man who declares he visited the pumping station at 9 p. m., the night of the accident, and found the engineer drunk.

FIG. 3.—ONE END OF BREAK IN RESERVOIR EMBANKMENT, GRAND RAPIDS, MICH.

ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

Entered at the New York Post-Office as Second-Class Matter.
Published every Thursday
at St. Paul Building, 220 Broadway, New York, by
THE ENGINEERING NEWS PUBLISHING COMPANY

GEO. H. FROST, - - - - - - - - - PRESIDENT.
D. McN. STAUFFER, - - - - - - - VICE-PRESIDENT.
CHARLES WHITING BAKER, SECRETARY AND MANAGING EDITOR.
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ALFRED E. KORNFELD, New York,
M. C. ROBBINS, Chicago,
S. B. READ, Boston,
C. F. WALKER, Cleveland, } ADVERTISING REPRESENTATIVES.

PUBLICATION OFFICE, 220 BROADWAY, NEW YORK.
CHICAGO OFFICE, 1636 MONADNOCK BLOCK.
BOSTON OFFICE, 170 SUMMER ST.
CLEVELAND OFFICE, OSBORN BUILDING.
LONDON OFFICE, EFFINGHAM HOUSE, 1 ARUNDEL ST., STRAND.

SUBSCRIPTION RATES: United States, Canada and Mexico, One Year, $5.00; 6 months, $2.50; 2 months, $1.00. To all other countries in the Postal Union: Regular Edition, One Year, $7.60 (31 shillings); Thin Paper Edition, One Year, $6.31 (26 shillings). SINGLE COPIES of any number in current year, 15 cents.

In requesting change of mailing address, state BOTH old and new address; notice of change should reach us by Tuesday to be effective for the issue of the current week. The number on the address label of each paper indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year; for instance, the number 320 means that subscription is paid to the 32d week (that is the issue of Aug. 9) of the year 1900; the change of these figures is the only receipt, unless one is sent by special request.

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The report of the committee on industrial education, read last week before the Society for the Promotion of Engineering Education, and printed in full elsewhere in this issue, deserves the widest publicity and fullest discussion that can be given it by the engineering profession and the press. One member of the society voiced the apparent sentiment of many, if not all, when he stated, in effect, that he believed the report marked an era in the development of education and industry in this country.

We refrain from further comment, gladly yielding our space to the presentation of the report in full, instead of giving a mere abstract, as would be necessary in the case of any ordinary report of such length.

A commendable feature of the work being done by the excursion committee of the Boston Society of Civil Engineers is the issuing of monthly bulletins relating to engineering in progress in New England; particularly, we presume, in the vicinity of Boston. The June bulletin contains notes on some fifteen pieces of work. The chief object of these bulletins, as we understand it, is to keep the members posted regarding what is going on, so that they may improve opportunities to visit such work as interests them. The society has frequent excursions to engineering work, generally occupying only half a day, and costing only a small sum for car fare. Aside from the interchange of ideas and good comradeship which these excursions promote, they greatly increase the number of visits to engineering works which the members make, since most people are so much more likely to take a trip in company with others than by themselves, and are very likely to postpone visits until it is too late to see work in progress unless there is a fixed date for going.

After years of strife and delay the city of Providence is again moving towards the filtration of its water supply. It has taken a committee two years to bring in a report in favor of mechanical filtration, notwithstanding the fact that some five years ago the city was on the point of contracting for a mechanical filter plant, after some months of experimental work. And even now the mayor and one member of the committee is averse to mechanical filtration, and the committee, in the same breath with its recommendation for mechanical filtration, recommends the appointment of a commission to investigate a source of supply. A variety of causes have contributed to this long struggle and delay. Some of the most potent of these appear to have been political, both in the best and the worst sense of that word; but with all the rest there have been honest doubts as to the relative efficiency and cost of mechanical and slow sand filtration, with further complications due to the desire of some to secure a supply naturally pure enough to render filtration unnecessary, and the fear of others, we suspect, that if either system of purification were adopted manufacturers on the Pawtuxet River would be called on to stop polluting the water supply. Whatever past excuses there may have been for delay are largely removed now, through the disappearance of litigation between mechanical filter companies, the relatively vast acquisitions to our knowledge of both slow sand and mechanical filtration and the growing belief that water thoroughly purified and then delivered to consumers without chance for further contamination is preferable to water from so-called naturally pure sources, particularly if the water is of surface origin. If there is much further delay in settling the water question at Providence, and particularly if the delay is accompanied by continued failure to submit the question to some disinterested expert engineer or engineers for final decision, outsiders will regard this long-protracted indecision as due to bad politics rather than good engineering.

The failure of the water-works reservoir at Grand Rapids, Mich., recorded elsewhere in this issue, teaches such obvious lessons that they hardly need to be pointed out; but even if Grand Rapids were the only place in the country where exactly similar conditions prevail, there are plenty of others where deficiencies or delinquencies equally bad, and in many cases worse, have existed for years, a fact that is of more significance than any single disaster, because it makes possible a whole series of disasters at any time. That a reservoir with earth embankments, particularly of sand, could be built and for 25 years maintained with no waste pipes or other means of discharging surplus water in case of over-pumping seems strange enough when only the possibilities of damages to the reservoir itself are considered; but when houses are as near by as those shown in one of the views accompanying our article describing the break, it is almost beyond comprehension that no safe and automatic means of escape was provided for the water when it passed above the normal water level in the reservoir. Bad as was the omission of a proper overflow, the failure to provide an automatic alarm to indicate when the water in the reservoir passed the normal level was perhaps worse, for in the absence of the overflow such an alarm was essential for safety. If the preliminary reports are true, the ordinary sight water gage in the pumping station was out of order, so it was useless in case of emergency; but what did that matter, if the engineer in charge was temporarily incapable of reading the gage, as the board of public works stated that he was on discharging him since the accident? Still, an automatic alarm would be pretty likely to waken a sleeping engineer, and might even bring a drunken man to his senses sufficiently to close down his pumping engine. If an automatic recording gage had been in service, its record would have been conclusive on some points, as soon as it could be inspected. Such gages are an essential part of any well-equipped water-works plant, being the best possible witnesses regarding pressures at the time of fires, breaks in water mains, or other accidents; besides which they may be of great assistance in studying the work of the pumping plant, including variations in pressure and economy of operation.

As might have been expected, the question of shutting down the Barren Island garbage reduction works by means of a legislative act has been taken into the courts of New York State and the enforcement of the act has been enjoined, pending a decision as to its constitutionality. As we have said in previous issues, sanitary questions like these, involving the prohibition of a certain industry in one part of a city, while permitting it elsewhere in the same city, and throughout the whole State, are properly for judicial, and not legislative, bodies to decide. The works in question are subject to orders from both the local and State boards of health, and if these are derelict, as is alleged, the courts are open to complainants. It may be urged that the courts are slow, but had the case been taken there first, instead of to the legislatures of both 1898 and 1899, it might have been decided before this. That the questions involved would go to the courts in any event, providing an attempt was made to annul contracts of such magnitude as these, might have been foreseen by any one of clear vision. We are glad to see that some of the newspapers of Greater New York, while still believing that the reduction works are a great nuisance, now realize that the proposed means of abatement are open to question. Further investigation and reflection might convince them that the conditions now are a vast improvement over those prevailing when the garbage was dumped at sea, to be subsequently deposited on miles of sea coast. It should be remembered that nowhere else in the world is one central authority attempting to dispose of such vast quantities of garbage by an improved method, as is the case in Greater New York. The garbage of the vast population of metropolitan London is collected by the many local governmental units making up that aggregation, and the means of disposal are almost as various in detail as the number of units, although where improved methods prevail burning is common to all. Berlin and Hamburg, it is probably true, have fine series of garbage furnaces or incinerators, but the total capacity in each city is small compared with the quantities taken to Barren Island, and would be smaller yet, in comparison, if the garbage, ashes and other refuse were mixed promiscuously here, as in the German cities named. In the various smaller English cities, as we pointed out in our issue of April 26, it is often the case that only a small portion of the refuse collected is burned; for instance, only 20% of the screened refuse of Glasgow goes to the furnaces, 80% being sent to the municipal farms and to other farms in the surrounding country. Lest this statement raise false hopes regarding the utilization of such wastes in agriculture, we hasten to add that from all over England come reports of the growing difficulty of inducing farmers to take these wastes on any practicable terms. Whether or not it would be wiser to burn the garbage after the present contract expires, or to continue some process of reduction, not necessarily the one now in vogue, can be determined only after propositions involving both methods have been invited and considered, providing responsible bidders under each scheme enter the competition. For a legislature, entirely ignorant of the vast sanitary and mechanical engineering questions involved, to annul a contract of this sort and prohibit the further use of the particular process employed is too ridiculous and dangerous a precedent to be tolerated.

THE LESSONS OF THE NEW YORK HARBOR FIRE.

With the disappearance of the first effect of horror following the destruction of life and property by the burning of the North German Lloyd steamships and piers in New York Harbor on June 30, people are beginning to ask to what the appalling rapidity and destructiveness of this conflagration was due and what the chances are of similar disasters occurring in the future. The dread of fire on shipboard is proverbial. No expense, no amount of incessant and patient vigilance, no cost of care and ingenuity are regarded

by men employed in ocean transportation as too great in providing against fire at sea. The wisdom of this caution has perhaps never been more strikingly illustrated than by the present disaster. When three great steamships and a large percentage of their crews can be destroyed by fire in a few hours in the very center of a busy harbor, with hundreds of willing helpers at hand, and land only a few hundred feet away; it is not difficult to account for the overwhelming alarm with which the peril of fire at sea is regarded, nor is it surprising that the traveling public is asking whether this danger of ocean travel is altogether necessary.

Briefly described, the conditions at the Hoboken piers of the North German Lloyd company when the fire started were as follows: The company's four steamers, the "Saale," "Bremen," "Main," and "Kaiser Wilhelm der Grosse," were lying in the docks. Their crews were at work cleaning, repairing and getting on supplies and cargo for the return voyage. Steam was down in the boilers, and the vessels were moored to the wharves with steel cables. The piers between the docks were timber platforms on piles, surmounted by larger open pier sheds of wood and corrugated iron. Inside the pier sheds and on the wharves around them were piled bales of cotton, barrels of whiskey and oil and combustible supplies and cargo of various kinds. The fire seems to have started in one of the cotton bales, spread to other parts of the piled up cargo and to the wooden pier sheds, and finally to the wooden superstructures of the ships berthed alongside them. The spread of the flames fanned by a stiff breeze was extraordinarily rapid, and inside of a brief half hour the pier sheds and piled up cargo were burning fiercely and the fire was rapidly enveloping the superstructures of the vessels.

As soon as the fire on the piers was seen to be beyond control the captains of the endangered vessels began to take steps to secure their safety; the ships' fire fighting apparatus were got in operation and men were set at work to cut the steel hawsers with axes, the fire raging on the piers preventing them from being cast off in the usual manner. After some delay all four vessels were got loose; the "Kaiser Wilhelm der Grosse," but slightly damaged, was towed to safety by the harbor tugs which had flocked to her assistance; the "Saale" was also towed, fiercely burning, down the river where she stranded on the flats off Ellis Island; the "Main" and "Bremen," also in flames, broke away from the piers and drifted up the river with the tide and stranded close together off Weehawken. Vigorous, but for the most part ill directed efforts were made to extinguish the fire on the "Main," "Bremen" and "Saale," but they were ineffectual in preventing the practically complete destruction of the combustible parts of the vessels and the death of the bulk of those imprisoned below decks. Altogether the killed number probably about 150 persons as the result of the burning of the three vessels and of the piers and adjacent property on shore. The total loss of property is estimated at between $5,000,000 and $6,000,000.

To one who reads the circumstances it is not strange that the magnitude and unexpectedness of this terrible disaster have been a serious shock to many persons. In one way and another the notion had grown up that the steel ship of today was largely exempt from the peril of fire, and the absence of any serious calamity from fire on shipboard during the last few years has strengthened this notion into something of a conviction that disaster by fire at sea was a risk peculiar to the old wooden vessel, which had ceased with the advent of the modern steel steamship. A brief study of shipping statistics would readily have shown the falsity of this notion as every person may prove for himself, but one does not need to go beyond an examination of the construction of the vessel itself to see it, as a brief explanation will disclose.

What we really have in a modern steel ocean steamer, so far as the peril of fire is concerned, is a steel hull covered over with a wooden decking and with a light iron superstructure, packed inside with inflammable woodwork and furniture. When once a fire obtains headway inside this superstructure, whose light interior heavily charged with paint and varnish make veritable kindling wood, all chances of egress from the hull below are effectually shut off. It is only a matter of a few hours then when the flames penetrate below and mete out destruction to all living and inflammable things. This is exactly what happened on the "Bremen," "Saale," and "Main" in the present instance and what would just as certainly have happened to the larger and more costly "Kaiser Wilhelm der Grosse" had she not been less exposed to the flames from shore and more expeditious in getting away from the place of danger. The same thing must evidently always occur whenever under any circumstances fire gains headway within the superstructure of modern steel steamships. The obvious remedy which occurs to everyone is to make these portions of vessels more capable of resisting the rapid progress of fire, and the most feasible method open for accomplishing this result seems to be to take a lesson from recent warship construction and employ only metal and "fireproof," or non-inflammable wood in the finish and housing of a ship.

To adopt the remedy suggested will require some modification in existing practice in ship fittings and furnishings, but this should not be difficult to obtain without involving any very serious disadvantages. Possibly it may involve some slight increase in weight and expense, but this can hardly be very great. Some denial may also be required in the luxury of elaborate wooden finish and furniture. With the present state of perfection in art metalwork, however, the loss in comfort and luxury of finish and decorations by substituting metal for wood in a great majority of the places where wood is now universally used on shipboard can hardly be considered of serious moment in comparison with the increased safety from fire which it would secure. Where wood is indispensable it can be rendered non-inflammable by one of several modern processes with remarkable success, as the records of the various tests published in the columns of Engineering News demonstrate and as its extensive use in recent warship construction in this country and abroad help to certify.

The opportunity for increasing the resistance of steel ships to the progress of fire is, moreover, not confined to their wooden structure. The whole cellular structure of the vessel above the water line is very poorly fitted to resist the progress of fire and to afford escape for passengers and crew in case of fire. This is evidently a more difficult matter to remedy than the excessive use of wooden finishings and housings, but ways will occur to any engineer of accomplishing it. There seems to be no good reason, for instance, why a vessel's portholes should be made so small that they cannot be used as a means of escape for passengers and crew in case the necessity arises. In the burning of the "Saale" dozens of persons lost their lives simply because their only chance of escape was prevented by the smallness of the ship's portholes. An obvious remedy in another direction would seem to be the dividing of the interior of the vessel into compartments to resist and confine fire as is now done to resist and confine the entrance of water in case of collision. This might easily be accomplished by the use of adjustable metal partitions or doors in the passageways where permanent bulkheads are impossible. It is probable, indeed, that proposals of this kind will be met by the assertion that the risk is too small to justify such excessive precautions, and there is, of course, a commercial limit to them so far as property risks go, but even here it is not quickly reached. The money spent in unnecessary decoration, and often in over-decorations, on many transatlantic passenger vessels would pay for a very large amount of construction designed purposely to retard the progress of fire in the interior of the ship.

A far more important and obvious lesson than the vulnerability of steel vessels to fire, which is taught by the recent disaster, is the necessity of some less combustible form of pier and warehouse construction and some safer provision for handling and protecting combustible freight so that conflagration is not endangered by every stray spark from a hoisting engine or the pipe of a careless wharf hand. To any one who has seen the flimsy wooden pier and warehouse construction which lines many sections of the New York Harbor front and who has witnessed the careless storing of cotton bales and oil and whiskey barrels, with their burst coverings and leaking contents, on the open wharves, the occurrence of the recent fire and its rapid spread will cause no surprise. The claim is perhaps true that these faulty methods are more prevalent along the Hoboken stretch of water front than at almost any other point in New York Harbor, but no part of the harbor line is free from them.

There can be no doubt where the remedy lies. Masonry piers, or if these are beyond obtaining, piers built of concrete and metal platforms on piles, and pier sheds of steel and brick or other fireproof construction are obviously the first desideratum, and the second is evidently to discontinue the storage of highly inflammable freight open to the danger of ignition by every stray spark and where its burning is certain to set fire to the shipping berthed in the adjacent docks. These are remedies which are easy of access, and their only objection is that they will cost more money than to continue the present practice. Such an excuse for flimsy construction and carelessness in handling combustible merchandise, however, has no more reason to be tolerated along the water line of a great city than in the center of its mercantile district. Certainly no building department would think of sanctioning such a structure as a pier and its shed away from the water front.

It is only just to say that there has been an improvement of late years in the construction of both piers and pier sheds in New York city itself. This better construction has extended to only a small proportion of the water front, however, and at best compares very unfavorably with the general advance in fireproof construction which has taken place in commercial buildings elsewhere in New York. A pier consisting of a timber platform surmounted by a great shed of steel framework, covered with corrugated iron and having its interior open from end to end and from roof to floor, cannot in any sense of the term be classed as fireproof construction. To substitute concrete and steel for the present timber pier platform and to divide the sheds by fireproof partitions and construct their framework and walls of steel and fireproof material, means, of course, increased cost and some more elaborate means of handling freight than the present hand trucks, but it insures a good chance of confining any fire which may break out in the stored freight to at most the inside of the pier shed and in the majority of cases to the interior of the compartment in which it originated. The $5,000,000 property loss of the Hoboken fire, to say nothing of the loss of the service of the three large vessels which were destroyed or of the deaths of over 100 of their crews, would pay for a large amount of the improved pier and pier shed construction of the kind which has just been described.

Two other features of the Hoboken fire which deserve notice in concluding these remarks are, the extremely hazardous methods of baling cotton which are generally employed and the inadequate provisions for fighting fires on shipboard with the present division of jurisdiction owing to parts of the harbor line being in two separate states. It cannot be doubted by any one who reads the newspaper accounts of this recent fire that a vast amount of time and labor was wasted in misdirected efforts both in removing the endangered vessels from their moorings and in fighting the flames on them, when once they were free from the burning piers. In the face of these facts it would seem that the suggestion, which has been made, that there should be some person or body of persons who should have supreme authority over the waters of the port in case of conflagration, is an eminently wise one. Regarding the baling of cotton it may be noted that a correspondent in this issue refers briefly to the growing use of round bales and their superior fire-resisting qualities as compared with the old square bale. We shall not take space to enter into a discussion of this question here, further than to say that the records of fire tests of round cotton bales which have been published by us from time to time indicate that the claims made by our correspondent are pretty fully borne out by facts.

LETTERS TO THE EDITOR.

The Stability of the Clay Cuts on the Silico Lake Ry., Nicaragua.

Sir: In your issue of May 17, 1900, there is an article descriptive of the "Silico Lake Railway and the Greytown Breakwater of the Nicaragua Canal Co." An illustration showing the steep side slopes in one of the cuts on this road is given, and in the course of the article there occurs the following statement: "This stiff clay soil will stand at a very steep slope in canal cuttings." Now, this particular cut, with slopes of about 5 on 1, is an exception, other slopes within a few thousand feet will not stand at 1½ on 1. The general belief that all clay in this region will stand almost vertically for an indefinite time is a mistaken one, and it is my opinion that if all cuts were taken out at 1 on 1 in the first instance much future expense and trouble would be avoided.

Respectfully yours, Thaddeus Merriman.

Greytown, Nicaragua, June 15, 1900.

Non-Combustible Cotton Bales and the Fire at the North German Lloyd Piers at Hoboken, N. J.

Sir: Having frequently noted the interest in accidents and disasters manifested in the columns of the Engineering News, I write you in order to bring to your attention certain matters bearing upon the recent fire at the North German Lloyd piers at Hoboken. If the information which I have gleaned from newspaper accounts is correct, it would seem that the initial cause of the fire was the accidental ignition of square bales of cotton. Owing to the magnitude of the disaster and to the fact that similar results are invited in the handling or transportation of square bales of cotton in an environment which must of necessity be shared by a large number of human beings, it is certainly of interest to know that a practically non-combustible package for cotton has been provided in the form of the Lowry bale. Repeated fire tests have been made, the records of which are available to any one interested, and I would add that, in the case of one of the ginneries of Weid & Neville, whose headquarters are at Houston, Tex., the plant was entirely burned to the ground, but 60% of the cotton contained in 150 Lowry bales stored therein was saved, the loss being due simply to the charring of the outside of the bales, for upon but two of the bales were any of the tie-wires broken. The rapidity with which fire spreads among square bales of cotton stored in the open, as in the case of a pier, renders it almost impossible effectually to control or even materially retard it, and it seems to me that a slow-burning package is the natural remedy.

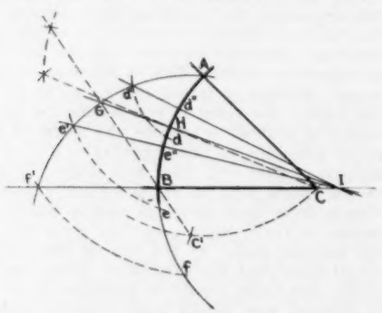
Yours very truly, Henry P. Jones.

No. 183 Essex St., Boston, Mass., July 2, 1900.

(The packing of cotton in cylindrical bales was described and illustrated in our issue of Dec. 16, 1897.—Ed.)

An Approximate Method for Dividing an Arc into Any Number of Equal Parts.

Sir: The following approximate method for dividing an arc or angle into any number of equal parts may be of interest to some of your readers: Let it be required to divide the arc AB or the angle ACB (see figure) into any number of equal parts, say three. Measure off on the arc AB, produced, three equal distances Ad, de and ef so that the arc Af will not greatly exceed in length double the arc AB. Swing the arc Af around the point A as a center until f coincides with CB, produced, at f'. Bisect



Af' and AB, passing a line through their centers G and H, and producing it until it intersects BC (produced if necessary), at I. Lines drawn through I and the division points d' and e' will divide the arc AB at d'' and e'' into the required number of equal parts.

My attention was attracted to the above method by its close resemblance to the method of dividing a right line, and if a line be taken as an arc with a radius infinity the proof would seem conclusive; however, there are restrictions which are quite easily seen and which need not be mentioned here. The error is quite perceptible if the arc AB is very large (exceeding two-thirds a semicircle) or if the arc Af greatly exceeds double the arc to be divided.

Robt. H. Moore.

Van Wert, Ohio, May 29, 1900.

An Ohio Decision Compelling the Award of a Contract to the Lowest Bidder.

Sir: Contractors will be interested in the decision recently rendered in favor of the Wagner Water Supply Co., of Dayton, O., by the Common Pleas Court of Montgomery Co. This company was the lowest bidder at the letting on May 9, for the excavation and back-filling of a deep trench for a 60-in. suction main. The trustees permitted the next higher bidder to alter his bid on account of an alleged mistake, and awarded him the contract under his altered bid. The company employed Mr. Walter V. Snyder as its attorney, and obtained a temporary injunction against the water-works board, and later applied for a writ of mandamus to compel the award of the contract to the Wagner Water Supply Co. After the filing of the application for mandamus, the trustees rescinded their former action and rejected all bids and readvertised. Upon final hearing the court allowed a peremptory writ of mandamus, and the trustees have accordingly entered into contract with the Wagner Water Supply Co. for the work.

One of the interesting points in the case was the defense that the right had been reserved to "reject any or all bids or waive defects in bids in the interest of the city." The court held that the city could not extend the authority conferred upon it by the statute, which required them to contract with the lowest bidder, unless, in the opinion of the city, he cannot be depended upon to do the work with ability, promptness and fidelity. Another point in the defense was that there was no money in the treasury to the credit of the water-works fund for this purpose on May 9, the date of the letting. This is an important point, for it is a common practice to sell bonds on the date of the letting or later, to raise the funds to pay for the contract. In this case bonds were sold on May 28 and the money was paid into the treasury on June 4. The court held that this was no defense, as the money was in process of collection, and that the board could have made a valid award on May 9, although it could not formally contract until the money was actually in the treasury.

Respectfully, C. W. S.

Dayton, O., June 25, 1900.

Further Methods for Computing the Quantities of Brickwork in Sewers.

Sir: The following rough and ready formula for calculating the number of brick in circular and egg-shaped sewers may be found useful and timely just now. So far as I know, it is original with me, though it may have been used by others before I discovered it. For circular sewers, multiply the radius in inches by the thickness of brickwork in inches; that is, R″ × T″ = number of brick per running foot. For egg-shaped sewers, multiply the horizontal radius (i. e., ½ hor. diam.) in inches by thickness in inches and add 25%. This will be found as accurate as anything except actually counting the brick, which will necessarily vary slightly in all cases. An approximate method of getting the number of cubic yards will be to divide the number of bricks by 540. I would not advise this, except in estimates, however, as it varies slightly from the exact quantities in different diameters. The formula is especially attractive because of its simplicity and the fact that it may readily be carried in one's head.

Very truly yours,

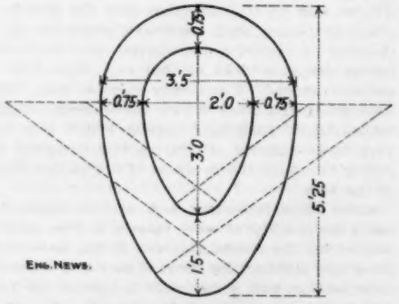
J. C. Meem.

395 Ocean Ave., Brooklyn, N. Y., May 18, 1900.

Sir: I notice on page 327 of your issue of May 17, 1900, a formula by Mr. S. M. Swaab for computing the quantity of masonry per linear foot in egg-shaped sewers; the formula being as follows:

Cubic feet per linear foot = 4.594 ($R^2 - r^2$), R being the radius of the outside of the arch, and r the radius of the inside.

The coefficient 4.594 was derived from a consideration of the relations between the radius of the inside of the



arch and the radii of the sides and invert of the inside of the sewer. It seems to me a fallacy is involved in assuming that this coefficient can be applied to R, as the relations between R and the other radii of the outside of the sewer are not the same as exist on the inside.

Taking the case of an egg-shaped sewer, with a vertical diameter of 3 ft., transverse diameter 2 ft., and a thickness of wall of 9 ins.; the vertical and transverse diameters of the outside of the sewer would be 4.5 and 3.5 respectively, the transverse diameter being 7-9 of the vertical, instead of ⅔, as it is on the inside. The quantity obtained by the above formula would be as shown in the following sketch, in which the transverse diameter is ⅔ of the vertical in each case.

The quantity of masonry per running foot of this sewer would be 9.5 cu. ft.

The diagram by Mr. Pierson, on the same page, gives 7.7 cu. ft. as the quantity contained in a sewer with a vertical diameter of 3 ft. and walls of a uniform thickness of 9 ins.; this agrees with the formula by Mr. Farley, given on p. 258 of your issue for April 19, 1900.

Respectfully, Frank S. Bailey,

Assistant in Eng. Dept., State Board of Health.

Boston, May 26, 1900.

(Other letters giving formulas and diagrams to the same end were published in our issues of April 19 and May 17, 1900.—Ed.)

Civil Engineering Exhibits at the Paris Exposition.

(Editorial Correspondence.)

Those who would restrict the term civil engineering to a certain particular field of engineering practice have never succeeded in drawing any hard and fast line to define where civil engineering leaves off and mechanical or electrical, or mining, or architectural engineering begins. Those who made the classification for the Paris Exposition have been no more successful. They laid down the rule, apparently, that all exhibits which had to do with transportation should be put in the department of civil engineering. This brought the very large class of carriages and motor vehicles into this department, and the latter, it will certainly be conceded, belong in the department of mechanical and electrical engineering. Such important tools of the civil engineer as the air compressor and the rock drill, however, are scattered all around; some in the civil engineering section, some in the department of mining and metallurgy and some in the machinery exhibit, both on the Champ de Mars and at Vincennes.

The general idea of classifying the exhibits in any such great exposition is an excellent one; but to carry it out fully involves enormous difficulties. Many exhibitors here, for example, have exhibits located in half a dozen or more different places, and the task of providing competent attendants for so many different exhibits becomes too great to be carried out. Again, the changes necessary to fill space on account of withdrawals here and overflows there finally result in many exhibits appearing entirely out of their proper place.

We have heard a great deal in America during the past two or three years about Anglo-Saxon supremacy in the industrial world. There is no sign of Anglo-Saxon supremacy in this Exposition, however. No one would ever suppose, from the exhibits here that Great Britain was the greatest exporter of manufactured goods among the nations, and that the United States leads the world in the volume of its manufactures. On the contrary, this Exposition is a great display of what the Gaul and the Teuton, the Slav and the Magyar, and the other races of Europe have done and are doing in the industrial arts; and none can deny that the showing is a most magnificent one.

Perhaps no field of the civil engineer's work is better represented in the Exposition than that of bridge construction. There are models, photographs and drawings in enormous number, showing bridges built in Europe and elsewhere by European engineers. In masonry bridges and viaducts, at least, Europe has nothing to learn from us, and no American engineer can view these substantial structures, which need no painting, or repairs, or inspection, and are good for any load, without feeling that we must soon undertake much similar lasting and durable work in the United States. When interest rates were 7% or more and when timber was very cheap and masonry, on the other hand, very costly, there was reason in the claim that it was cheaper to build a short-lived structure and replace it at intervals than to make the investment necessary for a permanent work. All these conditions have changed, however, and we can afford to build more permanent structures now than 20 or 30 years ago.

In the numerous examples of metal bridges shown in the Exposition one noticeable feature is the variety of design. There is no such predominance of the Pratt truss structure, with its rather unpleasing outlines, as in the United States. The arch is if anything the most in evidence; but this doubtless is because the most spectacular and pleasing structures have been chosen for exhibition here. Then there are suspension bridges, both link and cable, continuous girders, and trusses of many styles. Riveted work is the almost universal rule, but there are a few examples of bridges with pins and eye-bars.

Among the novelties in design in the French display is a model of a bridge built at Beuvron on the line from St. Aignan to Blois, last year. The designer evidently had heard something of secondary stresses and desired to have a bridge which should stand flexure at the joints without injury. He made his top and bottom chords of solid riveted construction without joints, but every web member where it meets the chord terminates in a flat plate perpendicular to the plane of the truss, and this plate is long enough to permit slight bending to take place from any flexure at the joints without unduly straining the metal. Of course the web members are made of a design to permit the plate. It is not at all a bad idea if one is to stick to riveted construction; and it must be remembered that European engineers, relying on shops unequipped with machinery for eye-bar manufacture, are practically tied up to riveted work, for all ordinary structures at least.

There are other novelties of which it is more difficult to see the reason. In the Russian exhibit is a model of a bridge on the Moscow-Karan Ry. It is a riveted span of considerable length and there is only a single floor beam at the center. This beam carries the ends of a pair of riveted deck-girder spans, the opposite ends of which rest on the abutments of the main span, and these deck girders carry the entire floor system and track. There may be advantages in the system in economy or ease of erection which are not apparent. It is at least one of the ways to build a bridge.

Here is another piece of novel construction, also Russian, on the Samarcand-Andigean section of the Central

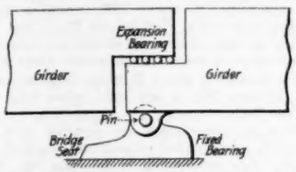


Fig. 1.—Sketch Showing End Bearings of Girders for Bridge on the Central Asian Ry.

Asia Ry., pretty well on the frontier, as a glance at the map will show. It is a bridge of seven spans of 17 meters each. The piers are piles of steel columns driven down through the sand to rock and suitably braced and latticed. These columns have a section like a Phoenix column of four pieces and a steel or cast-iron shoe is inserted at the bottom. These steel piers are too narrow at the top for the bridge seats of two spans, so the expansion end of each span is given a seat on a fixed end of the span next it, as shown in the accompanying sketch, Fig. 1.

Still another novelty in the Russian exhibit is a large model of the car shops for the Nicolas Ry., designed by Prof. F. Jassinsky, of St. Petersburg. The roof is a combination of an ordinary peak roof and the "weaving shed" idea, with the glazed side vertical. The design can be understood by the sketch in Fig. 2. Each main roof truss forms a peak, and the framing works out very simply and neatly.

I am inclined, on the whole, to credit Russia with having the most comprehensive and valuable exhibit of any nation in the civil engineering section. The exhibits of France and Germany are more striking to the casual visitor perhaps, but to the engineer searching for new departures and things of real professional interest and value there is a vast deal of material for study in the Russian section. Two examples must suffice: One of the troubles which beset the railway man in Russia is snow, and from the showing here made some of these Russian winters will bear comparison with Dakota blizzards or even with the mountain division of the Canadian Pacific. On the railways of the Southeast, which I presume reach the high plateau district of Central Asia, the subject of snow protection appears to have been carefully studied, and elaborate systems of protection of the track by planting trees and fixing snow fences have been devised. The trees are chiefly used, however. A large display of typical sections of the track are shown with nice cotton-wool snow banks, some of them over 20 ft. deep, burying the telegraph poles out of sight.

A large assortment of photographs shows the process of shoveling through these drifts; and there are peasants enough in the crowd, working on some of them, to populate a fair-sized town. There is also an elaborate report of an investigation made by one of the government engineers upon the various methods of snow protection for railways, and its writer devotes a column or so to the American rotary snow plow, of which he has formed a high opinion, although he does not seem to know it personally. Had he done so, he might have omitted the rest of his monograph. Experience enough has accumulated now on such roads as those in Colorado, and on the White Pass & Yukon Ry., in Alaska, to show that the rotary plow is the only thing to use on any road where push plows cannot keep the track clear.

The other example of the things of especial interest to an engineer in the Russian exhibit was the matter relating to the destruction wrought by floods on the Transcaucasian Ry. It appears that in the fall of 1895 this railway suffered from a regular Johnstown flood. Probably most American engineers never heard of it, but from the photographs shown the damage to the line was quite on a par with that which the Pennsylvania suffered in the Conemaugh Valley eleven years ago. It was not mere temporary construction that suffered either, but solid masonry, in many cases. In the work of renewal, of which photographs are shown, some astonishingly heavy work was done in the way of bank protection, etc.

One of the most interesting things to an engineer in the engineering exhibit is the extent to which money has been and is being lavished on the rivers and waterways of Europe. It is not for navigation only, but for bank protection, to control and regulate the course of the stream and prevent it from injuring fertile lands. The explanation is, of course, that this is a region where population is overcrowded. Land is the scarcest and dearest of anything, while labor is cheap and abundant. Some of these little mountain torrents in the Alps flow down through rocky valleys that look too steep and rugged to furnish food for a goat, yet one sees these streams carefully secured by barriers of hand-laid stone every few rods and by paving in the bed of the stream to prevent erosion. Such examples as this make clear to an American the great difference in conditions here and at home.

We have indeed undertaken some large scale bank protection works on the Mississippi and Missouri, and there are some fine models illustrating this work, exhibited here by the Mississippi River Commission. Such work, however, as laying down brick paving on river banks, or protection by wire mats and concrete, of all of which there are exhibits here, is something that is still beyond us.

In works for the improvement of navigation, natural and artificial, there is a great display, and the large models on exhibition of some of these European movable dams and the locks and viaducts on the canals gives one a vivid impression of what has been and is still being spent here on this class of work. Perhaps, under the conditions that obtain here, it is a wise expenditure. European railways seem unable to solve the problem of cheap and prompt freight transportation, as it has been solved in America; and apparently some radical revolutions must be made in their methods and material before they will render such service to the public as American railways render. Meanwhile, in Germany and France and Austria, such help as the waterways afford in the way of transportation is undoubtedly of great economic value to the community.

There is a large exhibit of dredging machinery, mostly by model, of course. The bucket and ladder is the prevailing type, but in the Russian Minister of Marine's exhibit there is a model of a large hydraulic dredge for the improvement of the Volga, labeled "Systeme Lindon W. Bates." On its general lines it resembles the famous "Beta," which Mr. Bates built for the Mississippi River Commission some years ago, and it is like that, a "whopper," with a nominal capacity of 1,500 cu. yds. per hour. According to the inscription, the dredge was built by the Cockerill Co., or Seraing, Belgium, one of the best known firms in Europe. The dredge has four suction pipes with revolving cutters out ahead, and these pipes are supported on a separate pontoon on each side, which is hinged to the hull at the rear. The boat is propelled by four screws, two at the stern and one on each side of the boat just opposite the pilot house. All these screws are driven by electric motors; but the rotating cutters are driven by a steam engine through a most complicated system of gearing, comprising three pairs of bevel gears and one pair of spur gears between the engine and the cutter head. I believe it was this train of gearing that made the "Beta" more remarkable for the frequency of its breakdowns than the size of its output. Mr. Bates at one time proposed to dispense with this gearing and drive the cutter heads by direct-connected electric motors, and it would appear to be a decided improvement.

Another novelty in this dredge worth noting is the sectional pontoon astern which carries the discharge pipe. This consists of a closed chamber of elliptical cross-section with the pipe running through its center.

I remarked that there was no full-size ladder dredge on exhibition. There is, however, a huge steam shovel of this type exhibited by A. F. Smulders in the Holland section. I am trying conscientiously to find the good ideas in all these foreign machines, which we ought to adopt, but I am unable to see how this machine can compare with our American steam shovels in efficiency for practical work. The ladder dredge, where it can deliver a whole scow load at a time, is no doubt a very efficient machine; but when it is mounted on wheels and set to loading gondola cars, and little four-wheel European cars at that, one is puzzled to see how it can work successfully at all. The machine is too large anyway for anything except the heaviest class of railway work, and it is too big to haul over the road without complete dismantling even without American clearance limits. It is probably designed for heavy canal work. I wish one of our American steam shovels were here so that European contractors might compare the two machines. There is a model of one in the United States section, but I fear it may not attract the attention it deserves.

In the Swiss pavilion there is shown a full-size section of the Simplon tunnel, with the drilling machinery in position and a large display of photographs, drawings, etc., illustrating the methods and materials employed in this great work. Weekly bulletins are posted from the headquarters of the contracting firm, Brandt, Brandau & Co., showing the rate of progress. On May 1 the north heading had been driven 3,092 meters and the south heading 2,270 meters, making 5,362 meters driven in all, or about 3⅓ miles. The progress made in the headings for the month of April and during the week ending June 3, was as follows:

	North heading.	South heading.
April	157 m. = 515 ft.	133 m. = 436 ft.
Week ending June 3.	34 m. = 111 ft.	29 m. = 95 ft.

As many readers of Engineering News will remember, this tunnel, like most of the other great Alpine tunnels, is being driven by Brandt hydraulic drills. It is a simple apparatus. The drill is a bar of steel with cutting lips formed on its end, and it is forced against the rock by a hydraulic piston and slowly revolved at the same time. The turning is done by a worm wheel on the drill shaft, which is driven by a worm turned by a small, duplex water-pressure engine. A jet of water enters the hole, keeps the drill cool, and washes out the chips as fast as they are made. A gang of four drills mounted on a heavy bar is used in the heading and the whole apparatus is carried on a car, so that it can be run back when a blast is to be let off. The bar is, of course, jacked against the sides of the tunnel to take the backward thrust of the drills when they are at work. This appears to be one of the limitations of the Brandt system. It works all right in a tunnel, but cannot be used on a tripod like the percussion drill. Apparently the Brandt machine could be improved greatly by the use of electricity instead of hydraulic power to rotate the drill. This would dispense with the heavy hydraulic pressure pipe system, which is an objection to the Brandt system. On the other hand, it would still not have the advantage of cooling and ventilation which is secured with the compressed air drill, and American engineers are likely to stick to that system.

Another Swiss railway exhibit which interests every American engineer is that of the Jungfrau Ry. Relief maps, photographs, etc., are shown and the work will be one which every engineer going to Switzerland will wish to visit. A new type of rack rail is to be used on this road, made by cutting a standard steel rail of the "Goliath" section so that it forms a rack. This system was selected as the result of an international competition and looks like the most solid and business like rack construction that has yet appeared. It is the invention of Mr. E. Strub, formerly Inspecting Engineer to the Swiss Government for all mountain railways.

These two enterprises, the Simplon and the Jungfrau, are the most important works in tunnel construction now under way in Europe, so far as I am aware. A tunnel scheme which would put everything else ever attempted in the way of tunneling in the shade is proposed at Marseilles, and maps and profiles of it are to be seen in the building devoted to the exhibits prepared by the Chambers of Commerce of the chief commercial cities of France.

This tunnel forms part of a scheme for a new canal to extend from Marseilles to the valley of the Rhone, a distance of 54 kilometers. It is proposed to make the canal section 2 meters in minimum depth and 46 to 50 meters wide except in some deep rock cuts and in the tunnel, where the width would be reduced to 22.50 meters. This

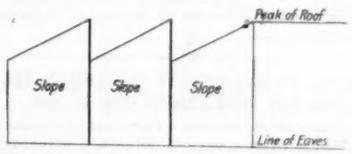


Fig. 2.—Sketch Showing Roof Construction of Car Shops for the Nicolas Ry., Russia.

remarkable tunnel is designed to have a height of 16 meters (about 52½ ft.), a width as above stated (about 73½ ft.), and its total length is to be 7,385 meters, nearly 5 miles. The total cost of the canal, tunnel and all is estimated at about $16,000,000. The proposition is to raise the cost by an assessment on the various cities and provinces which it is alleged would be benefited by the proposed work.

Another scheme, of which plans are on exhibition in the French section, is a proposed railway line to Timbuctoo, Africa, to be built by gradual extension of the Algerian railway system, which now terminates at Ain-Sefra in southern Algeria. From this point to Timbuctoo the distance is given as 2,150 kilometers. The popular idea of the district through which this line would run is that it is one vast desert, but the map of the line exhibited shows numerous streams—or at least blue lines—along the route. Very likely the climatic conditions may be no worse than those along parts of the Southern Pacific route. As for the traffic to be expected and the character of the population to be served by the road that is another matter.

Still another huge and airy scheme, which is brought to public attention in the French section is a ship railway, of which a model is shown, and which appears to be very

much on the lines laid down by our own Captain Eads many years ago.

In concluding this letter, a final word as to the progress and prospects of the Exposition may be of interest. As the month of June draws towards its close there is a noticeable decrease in the number of exhibits on which workmen are still engaged. By July 1 there will still be a very few incomplete exhibits, but so few as to be hardly worth mention.

The attendance, which was very small during the first month of the Exposition, has grown apace, as summer weather has come and the attractions have increased. Of course, the great bulk of the attendance—90% or more, probably, is the pleasure-loving Paris crowd, which turns toward the gates on every Sunday and fete day in enormous numbers, over 350,000 last Sunday, for example. The attendance from the French provinces and that from other nations is also rapidly growing, and there can be doubt that the Exposition is to be the great center of attraction for all Europe this summer.

A great deal has been published concerning the extortion of Paris hotels, the difficulty of obtaining quarters, etc., and it may have the unfortunate effect of deterring Americans from visiting the Exposition who would otherwise have done so. The facts are that the frequented and well known hotels of Paris are full, as similar hotels in any city always are when any unusual attraction increases the number of guests above the ordinary. There are, however, special hotels built for the Exposition—and far more substantial structures than those which surrounded Jackson Park at Chicago—and there are numberless apartments, boarding houses, etc., to be found by a little search, where, at the present time at least, there is no difficulty in securing accommodations. As to the expense, it can be made as much or almost as little as a person's preferences may dictate. In no city in the world is it easier to have one's money melt away; whereas, on the other hand, anyone desiring to economize can soon "learn the ropes" so as to live comfortably on a moderate allowance. C. W. B.

Paris, June 21, 1900.

NOTES FROM THE ENGINEERING SCHOOLS.

Manhattan College.—The trustees have decided to establish an Engineering Department in this institution to be co-ordinate with the School of General Literature. Courses will be offered leading to the degree of Bachelor of Science, in Civil Engineering, Electrical Engineering, and Architecture.

University of Michigan.—The new course in Marine Engineering and Naval Architecture will be offered to students with the opening of the University in September. Mortimer E. Cooley, now Professor of Mechanical Engineering, will give the instruction in Marine Engineering, and Herbert C. Sadler, Assistant Professor in Glasgow University, Scotland, has been appointed Junior Professor of Naval Architecture. The course as organized is a graduate course requiring five years' residence. At the end of the fourth year the student will receive the degree of Bachelor of Science in Engineering, and at the end of the fifth year the degree of Master of Science in Engineering.

STATISTICS OF RAILWAYS IN THE UNITED STATES FOR THE YEAR ENDING JUNE 30, 1899.

The statistician of the Interstate Commerce Commission, Prof. Henry C. Adams, has furnished to the press an advance abstract of the forthcoming twelfth annual report of the Commission, and from it we take the following figures of principal interest to our readers:

Mileage.—On June 30, 1899, the total single-track railway mileage in the United States was 189,294 miles, an increase during the year of 2,898.34 miles. This increase is greater than for any other year since 1893. The aggregate mileage, including tracks of all kinds, was 252,364.48 miles.

Equipment.—There were 36,703 locomotives in the service of the railways on June 30, 1899, or 469 more than the year previous. Of the total number reported, 9,894 are classed as passenger locomotives, 20,728 as freight locomotives, 5,480 as switching locomotives and 601 are not classified. The total number of cars of all classes was 1,375,916, an increase of 49,742. Of the total number, 33,850 are assigned to the passenger service, 1,295,510 to the freight service and 46,556 to the direct service of the railways. Cars owned by private companies and firms are not included in the returns made to the commission. The railways of the United States had on the average 20 locomotives and 734 cars per 100 miles of line; 52,878 passengers were carried and 1,474,765 passenger miles accomplished per passenger locomotive, and 46,303 tons of freight were carried and 5,966,193 ton miles accomplished per freight locomotive. All of these items show an increase when compared with corresponding items for the preceding year, ending June 30, 1898. There was also a decrease in the number of passenger cars per 1,000,000 passengers carried and a decrease in the number of freight cars per 1,000,000 tons of freight carried.

Both locomotives and cars being embraced in the term equipment, the total equipment of the railways on June 30, 1899, was 1,412,619. Of this number 808,674 were fitted with train brakes, the increase being 166,812, and 1,137,719 were fitted with automatic couplers, the increase in this item being 228,145.

Practically all locomotives and cars in the passenger service were fitted with train brakes, and of 9,884 locomotives assigned to that service, 6,128 were fitted with automatic couplers. Nearly all passenger cars were fitted wth automatic couplers. With respect to freight equipment, it is noted that nearly all freight locomotives were equipped with train brakes and 45% of them with automatic couplers. Of 1,295,510 cars in freight service, 730,670 were fitted with train brakes and 1,067,338 with automatic couplers.

Employes.—The number of persons employed by the railways of the United States as reported on June 30, 1899, was 928,924, or an average of 495 employes per 100 miles of line, an increase of 54,366, or 21 per 100 miles of line. The compensation of the employes of railways for 1899 represented 60% of their operating expenses and were 40% of their gross earnings.

The amount of railway capital outstanding on June 30, 1899, was $11,033,954,898. This represents a capitalization of $60,556 per mile of line. Of this amount, $5,515,011,726 existed in the form of stock. The amount of current liabilities not included in the foregoing capital statement was $554,330,022, or $3,042 per mile of line. The amount of capital stock paying no dividend was $3,275,500,181, or 59.39% of the total amount outstanding. The amount of funded debt, excluding equipment trust obligations, which paid no interest, was $572,410,746.

Public Service.—The number of passengers carried during the year was 523,176,508, showing an increase for the year of 22,109,827. The number of passengers carried one mile (passenger mileage) during the year was 14,591,327,609. There was an increase in the density of passenger traffic, as the number of passengers carried one mile per mile of line 1899 was 77,821 and in 1898 72,462. The number of tons of freight carried during the year was 959,763,583, an increase of 80,757,276 being shown. The number of tons of freight carried one mile (ton mileage) was 123,667,257,153. The increase in the number of tons carried one mile was 9,589,680,848. The number of tons carried one mile per mile of line was 659,565. These figures show an increase in the density of freight traffic of 41,755 tons carried one mile per mile of line.

The average revenue per passenger per mile for the year ending June 30, 1899, was 1.925 cts., for the preceding year it was 1.973 cts. The revenue per ton of freight per mile was 0.724 ct., while for 1898 it was 0.753 ct. An increase in mileage earnings is shown for both passenger and freight trains. The average cost of running a train one mile increased nearly 3 cts. as compared with 1898. The percentage of operating expenses to earnings shows a slight decrease as compared with the previous year.

Earnings and Expenses.—The gross earnings from operation were $1,313,310,618, being $66,284,497 more than for the preceding fiscal year. The operating expenses were $856,968,999, the increase in this item being $38,995,723. The income from operation, or the amount of gross earnings remaining after the deduction of operating expenses, generally designated as neat earnings, was $456,641,119, an increase as compared with the year ending June 30, 1898, of $27,288,774. The average amount per mile of line for 1899 was $2,435 and for 1898 $2,325. The amount of income received from sources other than operation was $148,713,983. The amount of dividends declared during the year, including $80,114 other payments from net income, was $111,089,936, leaving as the surplus from the operation of the year $53,064,877, the corresponding surplus for the year ending June 30, 1898, being $44,078,557.

Accidents.—The total number of casualties to persons on account of railway accidents during the year ending June 30, 1899, was 51,743. The aggregate number of persons killed as a result of railway accidents during the year was 7,123 and the number injured was 44,620.

REPORT OF THE BOARD OF ENGINEERS ON DEEP WATERWAYS FROM THE GREAT LAKES TO THE ATLANTIC.

The final report of the U. S. Board of Engineers, appointed to investigate and report upon the most available route for a deep waterway connecting the Great Lakes with the Atlantic Ocean was made public on July 7. The full text of the report had not been received by us up to the time of going to press, but from the very full abstract published in the "Detroit Tribune" of July 7, we have selected the following portions of most general interest to engineers:

Two routes are considered for getting from Lake Erie to Lake Ontario. One is from Tonawanda via Lockport to Olcott at the mouth of Eighteen-Mile Creek, a distance of 25 miles; the other is from Lasalle, below Tonawanda, on the Niagara River, to Lewiston on the Niagara River below the falls, a distance of 9 miles. This latter is the recommended route, though it presents some engineering difficulties. For 6 miles the whole cut is through solid rock, and the canal ends at Lewiston with a descent of nearly 320 ft. by means of eight double locks, of which six have a lift of 40 ft. each, and two of 39.4 ft. each. Concerning the respective merits of these two routes the report says:

The estimate for the Tonawanda-Olcott route exceeds the estimated cost of the Lasalle-Lewiston route, $6,000,550 for a 30-ft. channel and $2,136,900 for a 21-ft. channel. A steamship of 19-ft. draft in the 21-ft. channel would consume 1 hr. 9 mins. more time between Buffalo and a point common to the two routes in Lake Ontario in traversing the Tonawanda-Olcott waterway than by the Lasalle-Lewiston route, and that in a 30-ft. channel a steamship of 27-ft. draft would be 1 hr. 4 mins. longer by the Tonawanda route.

Since the cost of maintenance of the Lewiston waterway would be less than for the route from Tonawanda to Olcott, the interest and expense account will be much less for the former, and, as the actual time saved by a steamship on the Lewiston route would be from 11 to 16% of the time of passage, it is evident that both economy of construction and cost of transportation definitely determine the Lewiston waterway as the preferable route.

The natural harbor at the mouth of the Niagara River and the comparatively small amount of restricted channel on the Lewiston line make it a better location on which to construct a waterway than the route from Tonawanda to Olcott.

To get from Lake Ontario to the Hudson River two routes were considered. One was from Oswego on Lake Ontario, up the Oswego River to Lake Oneida, through that lake, across the divide at Rome and the Mohawk valley, and down the Mohawk River to Schenectady, then across country to Normans Kill, avoiding the great water power interests at Cohoes and Troy, and reaching the Hudson in the southern suburbs of Albany. The Hudson will require improvement as far south from this point as Germantown, about 25 miles from Albany. The mouth of Normans Kill is just 140.7 miles from the Battery at New York.

Two modes of construction are reported upon for the Oswego-Oneida route, called respectively the high and low level plans. One proposition is to cross the divide at Rome on a high level, locking up and locking down, establishing a great reservoir by damming the Black River at Carthage and conducting the water for 80 miles or more to feed the canal. The alternative proposition is to cut through the divide on the level of Oneida Lake, which will itself be the reservoir in that case for keeping the canal supplied with water. A supplementary reservoir may be constructed by damming the Salmon River, 30 miles away. The low level project is regarded as the preferable one, although costing $1,678,100 more at the outset.

The competing route from Lake Ontario to New York is down the St. Lawrence River to Lake St. Francis, and then across to Lake Champlain, which is entered a few miles above Rouses' Point. The lake is followed to Whitehall, at the southern extremity of the Narrows. From there a direct cut is made across to the Hudson at Fort Edward, a little below Glens Falls. The route becomes identical with the other, at the mouth of Normans Kill at Albany.

The actual number of miles of standard canal to be constructed by these two routes is almost exactly the same, 102.42 by Oswego, and 102.35 by Lake Champlain. There are 96 miles of river to be canalized by the Oswego route, and 134 by Lake Champlain. There are fewer locks by the Champlain route, but two of them must be tremendous affairs, having lifts of 52 and 48 ft. respectively. The lockage by the Lake Champlain route is really 292 ft. less than by the Oswego low level route, but the total distance is 208 miles longer by Champlain. It is estimated that the type of lake carrier taken for the consideration of these problems will use 12 hours more time going from Lake Ontario to New York by the Champlain route, although it would have to make 18 more lockages by the Oswego route.

The total distance from Buffalo to New York by the Lasalle-Lewiston route to Lake Ontario, and by the Oswego route to the Hudson will be 476.94 miles, and by the Champlain route to the Hudson, 685.21 miles. The total distance from Chicago to the Battery (New York) via the Lasalle and Oswego routes, is 1,367.6 miles, and from Duluth, 1,466.5 miles. The Champlain route increases these distances 208 miles. If the Olcott route were used in passing Niagara, 12 miles would be added. Concerning the comparative usefulness and value of the several routes, appendix 5 of the report says:

On the Champlain route the changes, except at Ft. Miller, will be beneficial to water power interests; but on the Oswego and Mohawk a rearrangement of several of the power plants will be necessary. At Oswego and on the Mohawk below Schenectady, all interference with power rights has been avoided by locating the routes outside the river valleys.*

Probably the most serious difficulty on either route will be to make satisfactory arrangements for railway crossings. This is especially the case in the Mohawk valley, where the river is paralleled by the four tracks of the New York Central R. R. and by the two tracks of the West Shore R. R. Ample provisions have been made in the estimates for either swing or bascule bridges for all crossings, but in the case of the New York Central R. R. crossing the number of trains is so great that a high grade crossing or a long embankment or an embankment and trestle may be necessary. With a slight readjustment

*The cut-off at Normans Kill is estimated to save $20,000,000 by leaving undisturbed the water-power rights at Cohoes and Troy.

of the railway lines in the vicinity of Rome, only one such high viaduct will be needed.

The estimated cost of these routes from Lake Erie to the Atlantic are as follows:

Champlain route	$183,420,600
Oswego-Mohawk route, high level	197,718,200
Oswego-Mohawk route, low level	199,396,300

Open navigation can be maintained on the Champlain route 230 days, and upon the Mohawk route 245 days, for average year. The round trip from New York to Chicago, including terminal detentions, will take 16 days 9 hours by the Champlain route, and 15 days 8 hours by the Oswego route; or, for a full navigation season, a steamship capable of making 12½ statute miles per hour in the open lake, and 8 miles an hour in the canals, would be able to make 14 round trips by way of Champlain, and 16 round trips by way of Oswego, during the season. A steamship could, therefore, transport freight from Chicago to New York by the Oswego route for 93% of the rate necessary to charge by the Champlain route, to make the same annual profit.

Assuming that freight can be transported over the improved waterway between New York and Chicago for an average rate of $1 per ton, the saving by the Mohawk route for an annual traffic of 30,000,000 tons would amount to $1,400,000. If the more expensive low level Mohawk waterway should be constructed, the first cost would be about $15,975,700 in excess of what it would cost to construct the Champlain route. If 3% interest be assumed as the rate paid by the government for the money used in constructing the waterway, the saving in the annual fixed charges due to the difference in the cost of the waterways would be $479,270, and for the difference in the cost of operation and maintenance $42,740, making a total of $1,132,010 in favor of the Champlain route, or about 80% of the amount saved on transportation rates by using the Mohawk waterway.

From a careful consideration of the type of ship best adapted for carrying the lake commerce, and of the depth of channels and waterways of the lakes and from the lakes to the Atlantic, required for such ships, it is evident that the proposed 21-ft. waterway will furnish better returns for the transportation of domestic and foreign commerce, than can be obtained by constructing a waterway 30 ft. deep, from the lake ports to the seaboard.

The channels already constructed at the Sault, at Lake St. Clair, and in the lower Detroit River conform to this depth. If a 30-ft. channel were built nearly 60 miles of excavation in deep water would be necessary to make the connecting channels of the upper lakes conform to the increased depth. The report points out that the interest on the increased expenditure, and the fixed charges of maintenance, would considerably exceed anything gained in diminished cost of transportation resulting from the building of deeper draft steamers. The limit seems to be therefore 21 ft., the carrier to have a draft of 19 ft. To build a 30-ft. channel for a carrier of 27 ft. draft, would not pay, comparatively speaking. Then there enters into the consideration the loss inflicted on vessel owners by the deeper channels, and larger vessels making smaller craft obsolete long before their time. Many coast harbors of the United States also suggest the same depth of 21 ft. and South American ports also.

The canal itself will be about 250 ft. wide at the bottom, with sides sloped to 300 ft. at the surface of the water. The surface width of the canal will be almost exactly that of the present St. Clair Flats canal. In rock excavations the slope of the sides will be much less, making the canal seem narrower. Around curves the surface width will be widened. There will be such construction that a speed of 8 miles an hour will be perfectly feasible in the canal. This is permitted at the St. Clair Flats canal, and vessels frequently exceed it. At no point in the waterway will there be a current greater than 4 ft. per second, or under 3 miles per hour. The ordinary current through the canal at the Flats is 1.7 miles per hour. Where rivers are canalized the width of the channel will vary with the amount of water to be taken care of, and will, in the Mohawk, vary from 250 ft. to 1,000 ft. Channels in the lakes and connecting rivers are expected to be 600 ft. wide at the bottom as a minimum. At the Sault the report advises the excavation of the channel from Hay Lake to Mud Lake to the west of Neebish, instead of trying to improve the present Hay Lake channel. In the lower Detroit River the only changes recommended are the straightening somewhat of the present channel by rounding off some corners.

The total cost of the proposed deep waterway, from Duluth to tidewater, with all its proposed regulating works, including the expenditures for damages to existing interest, and other charges of all kinds, is given as follows:

1. Via Lasalle-Lewiston (regulated surface). Oswego-Mohawk (high level plan).

	30-foot Channel.	21-foot Channel.
Lake Superior to Lake Erie	$33,539,869	$6,961,818
Lake Erie to Lake Ontario	73,435,350	42,393,206
Lake Ontario to tidewater	206,253,553	155,324,968
Totals	$313,228,772	$204,679,989

2. Via Lasalle-Lewiston (regulated surface). Oswego-Mohawk (low level plan).

	30-foot Channel.	21-foot Channel.
Lake Superior to Lake Erie	$33,539,869	$6,961,818
Lake Erie to Lake Ontario	73,435,350	42,393,206
Lake Ontario to tidewater	210,309,129	157,003,082
Totals	$317,284,348	$206,358,106

3. Via Lasalle-Lewiston (regulated surface). Champlain (with movable dams).

	30-foot Channel.	21-foot Channel.
Lake Superior to Lake Erie	$33,539,869	$6,961,818
Lake Erie to Lake Ontario	73,435,350	42,393,206
Lake Ontario to tidewater	213,123,864	141,027,415
Totals	$320,099,083	$190,382,436

THE TALBOT OPEN-HEARTH CONTINUOUS STEEL PROCESS AT THE PENCOYD STEEL WORKS.*

By Benjamin Talbot.†

In September of last year the author was enabled to put into practical work at the Pencoyd Steel Works, Pencoyd, Pa., a process for the continuous production of open-hearth steel, the results of which have been so satisfactory, both from a practical and theoretical standpoint, that they cannot, in the author's opinion, fail to interest manufacturers generally.

To-day two processes for the manufacture of steel stand pre-eminently before the world—the Bessemer and the open-hearth process. Both present certain advantages, and also certain disadvantages. The rapidity of the Bessemer is obtained only by a very lage initial outlay, and by heavy waste of metal. The open-hearth, on the other hand, whilst giving a far higher yield per unit of metal employed, demands a much longer time, and, consequently, heavy labor charges. As usually carried out, the general practice in open-hearth working is to charge solid pig iron and scrap into the furnace, and although attempts have been made to charge the furnace with molten metal, it has been found that no great advantage attends this method of working, since no refining is accomplished whilst melting down, as is the case when solid material is charged into the furnace. The rapid destruction of the furnace bottom has also been found in practice to militate against charging molten metal directly on to the hearth. Again, when solid material is charged into the open hearth, hours of valuable time are consumed before the furnace contains the necessary heat to enable the ordinary slag additions to be made in order to purify the charge, and convert the metal into steel of the desired quality.

In ordinary practice, when the bath of steel is finished the furnace is tapped and completely emptied, cooled off and repaired, and has to be heated up again before a fresh charge can be introduced to undergo the same cycle.

It is this point of intermittent refining, and the necessity of emptying the furnace and operating over a wide range of temperature, that appears to be the one upon which great improvements are possible in the output of the metal obtained in open-hearth practice.

Thus in the Bessemer, what is gained in time and labor is lost in yield; and the gain in yield in open-hearth practice is largely annulled by loss in time and cost of labor. Like all steel manufacturers, the author has given much time and attention to these questions, to see if it were not possible to manufacture steel by some process which, while giving the continuous production of the Bessemer, should also give the yield of the open-hearth. The process now at work at Pencoyd represents the results of his labors. To, in any way, approach the rapidity of Bessemer practice on the one hand, and the yield of the open-hearth on the other, the following conditions seem to be essential to success:

1. The use of fluid metal from blast furnace, mixer, or cupola, to avoid loss of time and oxidation by air during melting in the Siemens furnace, and to utilize the heat of the molten metal.

2. The oxidation of the metalloids should be effected entirely by means of solid oxides of iron, and not by the action of the air.

3. Maintaining by some suitable means a large reserve of heat to keep the oxidizing slags and metal in a fluid condition, and to insure the rapid removal of the metalloids from the molten pig iron.

In carrying out experiments on the refining of metal to remove the silicon and part of the phosphorus from very silicious iron, the author was particularly struck by the large amount of heat developed by the oxidation of the silicon, and the comparative immunity of the hearth from wear and tear, provided that the slag was never allowed to come in contact with the hearth, the latter being protected by a bath of metal, in other words, provided the bath was never emptied of metal. So impressed was he with these results that he determined to try if he could not carry the process further, and so modify it as to produce finished steel continuously; as, if this could be shown to be feasible, he saw that he would be able to carry into practice the three conditions necessary for economic production which have just been enumerated. In discussing this idea with many practical open-hearth operators and managers, the universal opinion was that the hearth would be speedily wrecked. However, whilst these opinions were discouraging, it was thought that they were based upon conditions which would not be encountered in the author's continuous method, as the following considerations will make clear.

The great trouble with hearths and bottoms of furnaces which, at times, arises in ordinary practice, both acid and basic, is brought about primarily by the action of the slag, and not by the metal. If after considerable work the face of a basic hearth is examined, it will be found to be nearly of the same composition as the slag produced in the furnace. In course of time the impurities in the hearth so increase that it becomes less refractory, and cannot withstand the heat of the finished steel when hot enough to cast, and consequently holes are formed, and especially is this the case if molten metal be poured directly upon this softened hearth. To overcome this drawback, the slag must be prevented from washing and impregnating the lower portion of the hearth every time the furnace is tapped. This can only be accomplished by flowing the slag off from the surface of the bath through a slag-spout at the foreplate level. Such a method of working naturally suggests a tilting furnace, from which any percentage of metal or slag can be poured out when desired. The furnace should also tilt in both directions, so that slag can be poured off from the opposite side to the metal.

Influenced by these considerations, the writer devised the present method of working at Pencoyd, which is carried out as follows: The furnace in use is a basic-lined tilting furnace of 75 tons capacity. The pig iron to be converted has an approximate composition of:

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
3.76	1.00	0.06	0.90	0.40

Owing to the absence of blast furnaces, this pig iron has to be melted in cupolas. The furnace should be charged on Sunday evening with about 50% molten cupola metal and 50% scrap, and this first (or filling) heat is worked down to steel in the usual way. When the bath is good finished steel, about one-third of it is poured off into a ladle and cast into ingots. No slag is run off with the steel. After tapping off this one-third of the charge, oxide of iron, in a fairly fine state of division, is added to the slag, and as soon as this is melted about 20 tons of molten cupola metal are run in to replace the steel tapped out. An immediate very active reaction takes place, during the continuance of which the gas is cut off from the furnace. The reaction has all the characteristics of the Bessemer blow during the elimination of carbon, a large volume of CO being given off, which immediately ignites and burns with an intense flame, the heat thus produced partly raising the temperature of the bath and partly being absorbed by the regenerators. After the metal has boiled vigorously for some 10 or 15 minutes, the slag, which is now almost deprived of iron oxide, is partly poured off, and the bath worked down into finished steel by the help of fresh additions of iron ore and lime. When the bath is ready one-third (or about 20 tons) of steel is cast, fresh slag additions are made, and another 20 tons of molten cupola metal run in as before. These operations are continued during the whole of the week, the furnace being completely emptied on the Saturday. The tap-hole is some few inches below the fore-plate level, so that no slag is taken in the steel ladle. This is arranged by stopping the hole sufficiently to prevent metal or slag working into it. When the furnace is ready to tap, it is tilted slightly, so that metal is above the tapping hole, a bar is plunged through, and the metal always runs first. As soon as the desired quantity is obtained, the furnace is tilted back over towards the charging side. This causes the level of the bath to fall well beneath the inside of the taphole, which makes it possible for the furnace helper to dry and clean it rapidly, and plug it up without delay.

Whilst this is being done, the slag line is examined, gas is turned on, and whatever repairs are necessary are made by throwing raw dolomite, or limestone, mixed with 5% pitch or resin, on the banks at a space from 6 ins. to 9 ins. above the level of the reduced bath. The surface of the bath is very useful, as it prevents the repairing material, in a great measure, from rolling down. It acts as a floor or foundation, and tends to hold the dolomite in place. Whatever does roll down becomes incorporated in the slag, and is beneficial.

In an empty furnace much basic material rolls down into the bottom, where it is not required, and in many cases tends to fill up the hearth.

About 3 hrs. 40 mins. is the period of time between two successive casts of steel at Pencoyd, and about 27 or 28 casts are usually made per week, including the filling and emptying heats. This number of charges, however, is obtained when starting with fluid metal on Monday night, as having only one cupola which has to be repaired each week end, it cannot be got ready before Monday evening. Starting on Sunday night, either with cupola or blast-furnace metal, and working at the same rate as during the other part of the week, from 32 to 34 charges would readily be obtained, increasing the output at least another 100 tons per week. It is not possible to give the actual consumption of fuel, as the furance is worked from the main gas tube, which supplies several other furnaces. It is interesting to note that from 25 to 33% less deoxidizers are required for the steel from this continuous furnace, than for the other furnaces, to give the same percentage of manganese (from .40 to .50%) in the finished steel.

Many hundreds of heats and thousands of tons of steel have been made by this method with very satisfactory results, all grades of metal having been produced, from dead soft up to .40 carbon steel. The question of excessive wear to the hearth, about which many doubts were entertained, and upon which the practicability of the method depended, has never given the slightest trouble, the hearth being practically in as good a condition as when put in eight months ago. This proves that a heavy surface reaction of short duration is confined to the bath, and does not affect the bottom of the hearth. As might be expected, the smaller the percentage of liquid cast iron added, the quicker this addition is purified. The data obtained proves this conclusively, as the higher the temperature the quicker the purification. It also indicates

*Abstracted from a paper read before the Iron and Steel Institute of Great Britain, published in London "Engineering" of June 22, 1900.

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TABLE I.
Liquid metal additions.

Heat No.	First—Calculated mixture—Carbon. %	First—Calculated mixture—Phosphorus. %	First—Analysis—Carbon. %	First—Analysis—Phosphorus. %	First—Reduction—Carbon. %	First—Reduction—Phosphorus. %	Second—Calculated mixture—Carbon. %	Second—Calculated mixture—Phosphorus. %	Second—Analysis—Carbon. %	Second—Analysis—Phosphorus. %	Second—Reduction—Carbon. %	Second—Reduction—Phosphorus. %	Third—Calculated mixture—Carbon. %	Third—Calculated mixture—Phosphorus. %	Third—Analysis—Carbon. %	Third—Analysis—Phosphorus. %	Third—Reduction—Carbon. %	Third—Reduction—Phosphorus. %
132	0.52	0.106	0.33	0.047	33	56	0.53	0.103	0.39	0.061	27	41	....	....	....	....	....	....
254	0.74	0.161	0.39	0.046	47	72	0.92	0.148	0.55	0.067	40	55	0.17	0.040	0.07	0.016	59	60
264	0.62	0.142	0.34	0.057	45	60	0.54	0.128	0.35	0.069	35	46	0.21	0.055	0.06	0.028	71	49
285	0.84	0.226	0.49	0.132	42	42	0.70	0.194	0.71	0.144	..	21	0.16	0.058	0.11	0.041	31	29
305	....	....	....	....	..	..	....	....	....	....	..	..	0.37	0.102	0.13	0.053	65	48
306	0.54	0.165	0.11	0.062	80	62	0.60	0.180	0.34	0.111	43	38	0.24	0.067	0.07	0.030	71	55
408	0.51	0.139	0.25	0.067	51	52	0.53	0.146	0.47	0.098	11	33	0.13	0.049	0.09	0.034	31	30

that furnaces of 100 to 120 tons capacity are quite practicable, and would be easily handled. In fact, with high-power gas, which does not require regeneration, this size will probably be surpassed.

It will thus be seen that the three conditions which the author considered necessary have been fulfilled. Liquid metal has been used without destroying the hearth, oxidation effected entirely by oxides of iron with concentration of the heat due to chemical action in the bath of metal, and also the heat developed by the combustion of the carbonic oxide evolved; and these conditions and the storage of a large reserve of heat to sufficiently assure the fluidity of both metal and slag, and promote rapid chemical action, are obtained by the simple expedient of maintaining a large bath of molten metal in the furnace, ever ready to receive fresh additions of molten furnace metal and oxidizing reagents. The retaining of this bath, or pool of metal, in the furnace is the vital and central feature of the process, and is the one upon which its success chiefly depends. It enables any grade of metal to be successfully used, the percentage of such metal added at any one time being varied according to its composition, and it also enables any quantity of steel to be drawn off to suit the requirements of the mills at the particular time. The high temperature of this large bath rapidly raises the temperature of smaller liquid additions, melts the oxidizing and basic materials added, and thus facilitates rapid chemical action, by which more heat is produced. It may be regarded as bearing the same relation to the process as the flywheel does to an engine, or the accumulators to the hydraulic press, acting as a storehouse of energy, ever ready to give it out when required. In the ordinary open-hearth furnace, during the melting period, one-third of the carbon and practically the whole of the silicon and manganese are oxidized by the air during melting, and thus they are not available as reducing agents in the bath; whereas in the process under consideration, the whole of these are available to reduce their equivalents of iron, and also the heat produced from their oxidation is practically concentrated in a very short space of time, with an increase in temperature of the bath similar to that produced by their combustion in the Bessemer converter. When it is remembered that, taking a metal with 3.5 carbon, 2.0 silicon, and 1.00 phosphorus, every 20 tons contains 14 cwt. of carbon, 8 cwt. of silicon, and 4 cwt. of phosphorus, it will be seen that both the reducing and heat-giving power of these constituents is not a mere piece of theory, but a practical fact.

That this is so is clearly seen by the results obtained in actual practice. In reference to the accompanying tables it will be found that the average yield extending over six weeks' consecutive working, has been more than 105; and that the percentage of added oxides, containing from 50 to 75% metallic iron, reduced, has been 25% by weight of the metal, whereas in ordinary open-hearth practice about 10 to 15% is the maximum which can be used.

As regards the practical management of the furnace, and the question of repairs generally, a few words may now be added.

During recent years the tendency in open-hearth practice has been constantly to increase the size and capacity of the furnaces, with the result that larger ladles, cranes, etc., have to be employed to deal with the increased weight of the cast. Owing also to the length of time between each cast, the mills are not kept regularly supplied with ingots, being often unduly pressed immediately after tapping, and having to wait before the next cast can be tapped. One of the advantages of the process, as carried out at Pencoyd, is the regularity with which the mills can be supplied with ingots, and the weight of the metal cast regulated in accordance with the requirements of the rolling department.

With reference to the important question of scrap in connection with this method of working, solid scrap has been charged into the steel bath many times to observe whether any saving of time could be effected by dilu... the carbon and phosphorus; but its chilling effect wa... pronounced that the heats could not be made as ra... as when the impurities were eliminated by the usual ... of iron additions. In fact, if it were possible to intro... the basic additions in a liquid condition rather than ... the temperature of the bath would be appreciably b... fited. It is probable that the present practice of cha... furnaces with cold scrap, and melting this down i... oxidizing flame, which results in a large waste of iro... wrong. The question has been put, What is propose... do with scrap when using the continuous method? ... answer is, if it cannot be disposed of profitably, put ... that is suitable through the blast furnace. This is ... most efficient melter we have, both as regards fuel ... waste. The scrap will also be carbonized, and will bec... cast iron. In the large bath of pure metal, stored, ... have a more than efficient substitute for cold scrap, a... is standardized in quality, and is in liquid condition.

If, therefore, we can melt scrap, impregnate it w... carbon for less fuel, and with less waste, than is now taken in melting and oxidizing it in the open-hearth fu... nace, it should be more economical to put it through the blast furnace. By eliminating the carbon from this metal again, more oxide of iron can be reduced, and a better yield obtained, than if it were simply charged direct into the steel furnace in its decarbonized condition. The period of time will also be saved to the steel department which is now lost in charging scrap in detail, and waiting for its melting. This represents a serious loss in labor alone, as the leading men employed upon the furnace are skilled melters, earning large wages for refining metal. They may as well be kept busy at this purification, rather than wait for hours before obtaining a satisfactory refining temperature.

Possibly many steel works' managers may rather object to what may seem equivalent to writing their scrap down to pig-iron price; but, after all, this is only a question of figures, and the actual value of the metal is not affected whether it is melted in a blast-furnace cupola or open hearth, except in so far as one is a cheaper melter than the other. In cases, however, where it may not be advisable or convenient to melt in a blast furnace, one or two ordinary fixed Siemens furnaces working 75 to 80% scrap, by which means four to five heats can be obtained from each furnace in 24 hours, will readily deal with all the scrap produced. In all Siemens works, with exception of large plate mills, the difficulty is not so much to deal with scrap as to obtain sufficient quantity at a reasonable price, to enable 20 to 25% to be used in the open hearth. No doubt this is especially felt at present prices.

TABLE II.

Heat No.	Time—Charging—Commenced.	Time—Charging—Finished.	Time—Heat tapped.	Time—Hours in furnace. h.	Time—Hours in furnace. m.	Charges—Cold pig iron, lbs.	Charges—Liquid metal, lbs.	Charges—Ore—Iron lbs.	Charges—Ore—Manganese, lbs.	Charges—Cinder, lbs.	Charges—Scale, lbs.	Charges—Limestone, lbs.	Charges—Ferro-Manganese, lbs.	Charges—Silico-spiegel. lbs.	Product—Ingots, lbs.	Product—Scrap, lbs.	Product—Per cent. gain, lbs.	Analysis.—Carbon, %	Analysis.—Sulphur, %	Analysis.—Phosphorus, %	Analysis.—Manganese, %
243[1]	6:40 p.m.	5:50 a.m.	8:00 a.m.	14	00	3,000	53,000	8,000	.....	.....	.....	4,500	300	100	51,500	2,100	..	0.17	0.046	0.033	0.52
244	9:45 a.m.	2:30 p.m.	3:00 p.m.	5	15	400	44,500	8,000	.....	.....	3,000	4,500	140	75	34,605	1,950	..	0.14	0.047	0.071	0.42
245	4:35 p.m.	8:16 "	8:35 "	4	05	500	40,800	7,000	.....	.....	3,500	4,500	125	75	36,595	800	..	0.17	0.051	0.075	0.55
246	9:45 "	1:30 a.m.	1:45 a.m.	4	00	500	31,300	4,500	.....	.....	3,500	4,500	125	75	35,225	900	..	0.16	0.046	0.058	0.56
247	2:15 a.m.	6:30 "	7:15 "	4	00	600	33,700	4,500	.....	.....	3,550	4,500	140	75	38,500	3,100	..	0.14	0.038	0.063	0.52
248	8:35 "	12:25 p.m.	12:45 p.m.	4	10	800	37,800	5,000	400	.....	3,500	4,500	140	75	36,240	950	..	0.16	0.050	0.050	0.42
249	1:45 p.m.	5:50 "	6:05 "	4	30	500	37,500	5,000	400	.....	3,500	4,500	125	75	36,450	1,150	..	0.12	0.061	0.073	0.48
250	7:15 "	10:30 "	10:50 "	3	35	500	34,100	5,000	500	.....	3,500	4,500	125	75	36,825	1,000	..	0.12	0.053	0.033	0.42
251	11:30 "	2:45 a.m.	3:00 a.m.	3	20	500	33,100	5,000	500	.....	3,500	4,500	125	75	37,345	1,500	..	0.12	0.054	0.045	0.49
252	4:00 a.m.	7:10 "	7:45 "	3	45	600	38,800	3,800	400	.....	.....	4,500	140	75	37,730	2,400	..	0.16	0.046	0.035	0.44
253	8:50 "	11:40 "	12:00 noon	3	10	600	34,900	2,000	400	3,000	3,000	4,500	140	75	37 625	2,200	..	0.19	0.040	0.034	0.57
254	12:55 p.m.	3:30 p.m	3:50 a.m.	2	55	600	34,400	2,000	400	.....	3,800	4,500	140	75	37,405	1,200	..	0.14	0.038	0.020	0.52
255	4:35 "	7:00 "	7:15 "	2	40	500	31,800	5,000	....	.....	3,500	4,500	125	75	38,385	900	..	0.10	0.046	0.047	0.34
256	8:35 "	11:20 "	11:40 "	3	15	500	42,700	2,000	....	5,000	.....	4,500	125	75	38,150	850	..	0.14	0.055	0.071	0.57
257	12:45 a.m.	3:40 a.m.	4:00 a.m.	3	15	500	40,500	2,000	....	5,000	3,500	4,500	125	75	37,935	1,150	..	0.13	0.058	0.060	0.56
258	5:00 "	8:30 "	8:50 "	3	50	600	37,300	6,000	....	.....	.....	4,500	140	75	37,155	2,400	..	0.38	0.057	0.072	0.58
259	9:55 "	1:30 p.m.	1:45 p.m.	3	50	600	34,200	300	400	5,200	3,600	3,900	140	75	39,930	1,750	..	0.14	0.036	0.028	0.54
260	2:50 p.m.	7:00 "	7:15 "	3	50	600	40,600	2,000	500	4,600	3,500	4,500	125	75	35,655	2,800	..	0.19	0.055	0.047	0.53
261	8:30 "	12:41 a.m.	1:00 a.m.	4	30	600	40,900	2,000	500	5,000	3,500	4,500	125	75	36,960	2,200	..	0.19	0.057	0.054	0.55
262	2:05 a.m.	5:20 "	5:35 "	3	30	600	35,700	6,000	500	.....	3,500	4,500	125	75	37,775	2,050	..	0.16	0.045	0.060	0.54
263	6:30 "	9:35 "	9:50 "	3	20	600	38,300	....	400	5,000	3,500	4,500	140	75	37,205	1,900	..	0.15	0.040	0.027	0.53
264	11:50 "	2:03 p.m.	2:15 p.m.	3	10	1,000	35,000	2,700	400	2,500	4,200	4,800	140	75	39,100	1,850	..	0.14	0.038	0.030	0.39
265	3:20 p.m.	7:20 "	8:10 "	4	50	600	41,100	4,600	400	.....	3,000	4,800	125	75	38,590	1,100	..	0.13	0.036	0.034	0.46
266	9:15 "	12:05 a.m.	12:25 a.m.	3	10	600	35,900	5,000	400	5,000	3,500	4,500	125	75	38,090	1,150	..	0.16	0.034	0.063	0.55
267	1:25 a.m.	5:00 "	5:25 "	4	00	600	38,400	1,000	400	5,000	3,000	4,500	125	75	38,530	1,100	..	0.16	0.042	0.052	0.50
268	6:24 "	9:35 "	9:50 "	3	25	600	36,700	5,000	400	.....	.....	4,500	330	100	62,170	4,850	..	0.16	0.042	0.035	0.48
269	11:20 "	12:45 p.m.	6:45 p.m.	7	25	800	60,000	9,000	500	.....	5,000	6,300	330	100	66,675	1,000	..	0.17	0.051	0.041	0.61
270	6:45 p.m.	....	7:30 "	0	45	1,000	....	.....	.....	.....	.....	1,000	330	100	52,510	4,200	..	0.14	0.049	0.055	0.44
339[2]	6:00 "	10:15 "	9:30 a.m.	15	30	1,300	95,700	1,580	1,250	9,500	.....	1,500	140	50	41,780	1,250	..	0.13	0.059	0.051	0.36
400	11:20 a.m.	4:00 "	4:15 p.m.	4	55	1,300	38,600	4,800	800	.....	3,200	4,700	140	50	38,320	400	..	0.12	0.060	0.043	0.34
401	5:25 p.m.	10:40 "	10:50 "	5	25	1,000	40,600	5,500	900	.....	3,400	3,400	125	50	38,480	2,315	..	0.14	0.052	0.073	0.49
402	11:30 "	4:15 a.m	4:30 a.m.	5	00	2,000	38,700	5,810	900	.....	3,500	4,650	125	50	45,040	2,150	..	0.15	0.055	0.049	0.34
403	5:30 a.m.	10:30 "	11:00 "	5	30	1,500	42,600	5,700	800	.....	4,700	3,500	140	50	38,280	1,960	..	0.17	0.055	0.083	0.48
404	11:15 "	5:05 p.m.	5:15 p.m.	5	20	1,200	42,100	4,400	400	.....	4,100	3,600	140	50	38,080	675	..	0.14	0.048	0.064	0.53
405	5:45 p.m.	10:25 "	12:30 "	4	50	800	40,000	900	900	5,200	3,400	4,400	125	50	41,270	480	..	0.14	0.056	0.053	0.47
406	10:05 "	3:10 a.m.	3:20 a.m.	4	15	800	40,500	1,700	900	4,850	4,000	4,500	125	50	39,120	950	..	0.16	0.061	0.058	0.46
407	3:55 a.m.	8:40 "	9:00 "	5	05	600	45,600	3,200	400	4,900	4,000	5,000	140	50	38,835	1,250	..	0.15	0.056	0.075	0.57
408	9:55 "	1:10 p.m.	1:30 p.m.	3	35	800	36,200	4,400	500	2,200	4,000	3,900	140	50	38,650	1,270	..	0.13	0.054	0.035	0.44
409	2:45 p.m.	6:25 "	6:45 "	4	00	900	35,100	700	750	3,900	3,500	4,600	125	50	39,170	1,340	..	0.13	0.047	0.036	0.49
410	7:20 "	11:15 "	11:25 "	4	05	900	41,300	2,100	1,250	4,300	3,400	5,300	125	50	39,480	1,030	..	0.14	0.060	0.049	0.43
411	12:00 a.m.	4:30 a.m.	4:40 "	4	00	900	40,600	1,500	1,100	4,150	3,600	5,200	125	50	37,850	940	..	0.16	0.061	0.048	0.49
412	5:35 "	9:05 "	10:00 a.m.	4	25	1,800	39,200	1,100	800	3,500	3,700	4,000	125	60	39,025	620	..	0.30	0.071	0.058	0.48
413	11:15 "	2:05 p.m.	2:40 p.m.	3	25	650	38,400	.....	900	4,400	4,000	4,300	125	75	45,965	950	..	0.41	0.056	0.020	0.50
414	3:50 p.m.	7:55 "	8:05 "	4	15	800	37,800	2,750	1,600	4,300	3,600	5,200	125	50	38,260	1,010	..	0.20	0.062	0.029	0.47
415	8:45 "	12:35 a.m.	12:45 a.m.	4	00	2,000	41,400	5,600	1,200	.....	4,050	5,000	120	100	39,405	890	..	0.20	0.062	0.036	0.44
416	1:35 a.m.	5:30 "	5:45 "	4	10	1,000	35,100	5,100	1,000	.....	3,600	2,800	125	50	39,375	525	..	0.14	0.064	0.037	0.41
417	6:15 "	9:05 "	11:30 "	5	15	1,450	34,300	5,150	1,000	.....	3,500	7,100	160	75	44,785	1,235	..	0.17	0.055	0.043	0.40
418	12:15 p.m.	3:00 p.m.	3:45 p.m.	3	30	850	37,900	5,150	1,000	.....	3,500	3,800	160	75	44,580	850	..	0.24	0.063	0.069	0.48
419	4:30 "	8:25 "	8:35 "	4	05	800	39,100	5,100	....	.....	3,500	4,400	125	50	39,110	1,285	..	0.14	0.049	0.046	0.52
420	9:05 "	12:30 a.m.	12:40 a.m.	3	35	1,600	35,200	.....	....	.....	3,700	4,800	125	50	38,365	2,320	..	0.15	0.049	0.027	0.46
421	1:10 a.m.	4:00 "	4:10 "	3	00	2,000	36,500	2,300	....	1,750	4,000	5,000	125	50	38,700	1,090	..	0.19	0.045	0.042	0.40
422	5:00 "	9:15 "	9:40 "	4	40	1,200	40,200	1,000	....	4,800	3,750	3,100	350	100	66,910	350	..	0.15	0.059	0.056	0.54
423	10:30 "	11:35 "	5:40 p.m.	7	10	1,300	59,400	.....	....	7,600	5,400	7,700	330	100	69,650	1,610	..	0.11	0.055	0.030	0.52
424	5:40 p.m.	....	7:00 "	1	20	1,200	.....	.....	....	.....	.....	500	330	100	67,310	2,960	..	0.10	0.057	0.041	0.47
425	7:00 a.m.	....	7:55 "	0	55	500	.....	.....	....	.....	.....	.....	100	50	20,500	5,960	..	0.08	0.070	0.029	....
Total						50,550	2,099,000	202,210	30,850	110,150	168,700	241,650	8,580	4,460	2,277,244	88,305	11.4	....	....	....	....

[1]Heat No. 243 had 49,300 lbs. of scrap. [2]Heat No. 399 had 22,750 lbs. of scrap

In some cases it may be found convenient to establish a storage of liquid metal between the blast furnaces and the steel furnaces. In this event the usual mixer used in Bessemer practice will be very suitable. If the metal stored should be very silicious, it might be better to perform a certain amount of purification whilst being held. This vessel could then be a furnace, basic lined, so that an oxidizing slag could be carried, which would have a refining influence upon the liquid metal added from time to time.

This preparatory furnace would quicken the operation in the finishing furnace, for if the silicon were practically eliminated, and the carbon somewhat reduced, the metal would be purer and hotter, and so would expedite complete purification. It is not anticipated, however, that this will be necessary except in special cases, as one of the advantages of the process is the ease with which it lends itself to the production of steel from blast-furnace metal of irregular composition, owing to the large extent to which the impurities are reduced by dilution as apart from oxidation. Thus, assuming that 20 tons of molten pig iron containing 3.0% of silicon were teemed into the bath of 40 tons of molten finished steel, the silicon by mere admixture would be reduced in the resulting metal to 1%, which is not an abnormal percentage for basic Siemens work, and, as this would be almost immediately oxidized, the somewhat silicious slag could be flowed off before it would have time to seriously attack the banks of the furnace, even if sufficiently acid to do so. This continuous method should certainly be worthy of the consideration of acid open-hearth steel manufacturers, even if they discarded the acid lining, and took up the basic, which lends itself so satisfactorily to the process. Acid bottoms gave way to the basic in puddling, and there is apparently no reason why history should not repeat itself in the case of steel.

In this age, when on the one hand the difficulty of obtaining hematite ores which will produce a pig with less than .05% of phosphorus is becoming greater and greater, and on the other hand engineers are more stringent than ever in insisting upon low phosphorus material, the adoption of this process with a basic lining would enable all those ores just outside hematite limit to be used, and the steelmaker might with absolute certainty depend upon a finished steel produced with under 0.03% phosphorus; when using hematites, iron of present grade, say under .06% of phosphorus, still lower desults would be possible.

The highest desideratum of any lining is to be passive, whilst the metal it holds is under treatment, and when this result is obtained with a basic hearth, it should be used even if the pig metal is sufficiently pure not to require dephosphorizing, providing the steel is made at a less cost. The attached tables give the history of various heats analyzed. They attempt to give a record of materials charged, and time consumed in purification.

TABLE III.—Analysis of Slag at End of Week When Emptying the Furnace.

	1899		1900		
Week ending.	Nov. 25,	Dec. 2,	Jan. 6,	13,	Feb. 17,
	%	%	%	%	%
Iron protoxide (calculated)	16.61	19.02	18.23	17.24	20.21
Silica	18.79	11.42	14.52	15.60	12.08
Calcium oxide	37.65	40.62	40.69	38.29	38.08
Magnesium oxide	7.37	6.01	6.45	9.36	5.93
Phosphoric anhydride	7.08	8.04	7.85	7.56	8.63
Manganese oxide	8.91	11.69	9.70	9.75	12.40
Metallic iron	12.92	14.79	14.17	13.40	15.72
Metallic phosphorus	3.09	3.51	3.42	3.29	3.64

	Metallic iron, %	Silica, %	Phosphoric anhydride, %
Port Henry iron ore	58.00	3.00	4.35
Scale	74.50	0.50	0.07
Cinder	66.80	8.00	0.23

TABLE IV.—Summary of Six Weeks' Working, Starting With Fluid Metal on Monday Night.

Average number of heats per week	27
Number of hours in the furnace*	3.8
Weight of metals charged per week (long tons)	488
Weight, ingot and scrap, per week (long tons)	517
Yield, ingot and scrap pr 100 parts metal chrgd	105.94

*Exclusive of filling and emptying heats.

Many analyses have proved that the silicon is oxdized immediately, and practically disappears during the reaction, as it has never been found above .02 in the bath.

In one of the heats the silicon was determined to observe its elimination. The slag covering the steel bath left in the furnace contained 11.86 metallic iron. An addition of 2,700 lbs. of scale and ore raised the metallic iron to 25.14%. The steel bath contained .009 silicon. An addition of 15,100 lbs. of liquid metal containing 1.22 silicon was purified to the following extent in a period of 10 minutes: i. e., silicon 91%, carbon 36%, phosphorus 56%. From the second ladle addition 88% of silicon is removed.

An investigation of Table "B" will show that the heats are made up of three ladles of metal; the first two contain practically all the charge, the third small addition being made after the others are purified, and is poured in shortly before tapping. They indicate most plainly that the second addition of liquid metal is not purified as rapidly as the first. This is shown in the composition of the metal after the first reaction, as the greatest amount of purification is always obtained from the first addition, when the bath is purer, hotter, and is also covered with a highly oxidizing slag.

When the second addition is made these conditions are not there, as the metal is higher in metalloids, the slag poorer in oxide of iron, and the bath cooler from the large quantity of cold basic additions made after the reaction. These additions, especially the lime, take some time to liquefy. This can be remedied by increasing the size of the furnace, so that a smaller percentage of liquid metal can be worked in any given charge, and still have the quantity poured out of the furnace at any one time sufficient in weight to suit the shop practice. Of course, this question of the weight of heats depends upon the ladle and size of ingots. In our case at Pencoyd, about 20 tons is the minimum quantity we care to handle. A furnace of 100 tons capacity, working not more than 20 to 25% of liquid pig metal, in and out, would yield heats in considerably less time than we are obtaining them at present. This result must be obtained because less purification would be necessary; a smaller percentage of basic additions would be used, and the temperature of the bath would not be so much reduced.

This question of temperature is very vital for rapid work. The tests taken confirm this. We had a bath of 104,000 lbs. of metal finished and hot enough to tap, covered with a slag containing 22.42 metallic iron. Into this bath was poured 9,300 lbs. of liquid cast iron. Four minutes were taken to pour this in, and two minutes afterwards the bath was a good quality of soft steel, and the metal was hot enough to tap. The slag also was reduced to 12.42 metallic iron.

This is approaching, if not surpassing, the speed of a Bessemer converter, in purification, and we have only to double the size of the steel bath and liquid cast iron addition to obtain about as large a quantity of metal as some converters treat.

It therefore appears that every care should be taken to keep the metal as near as possible to a satisfactory pouring heat, and this can be helped by the design of the furnace. The capacity of the furnace can be increased every time practice has proved that the one in operation can be safely enlarged. What the practical limit of size will be we cannot say with our present limited knowledge, but if furnaces of 200 tons capacity come into use the output of steel will be very arge, as an addition of 10% of liquid metal would be purified in a few minutes, and its temperature sufficiently raised in the same short period of time. Working under these conditions would keep the temperature as near constant as possible, and the gas would speedily restore the heat.

If the accompanying tables are consulted some interesting results will be observed. They confirm the work and deductions of those eminent investigators, Sir Lowthian Bell and Mr. Snelus, who were amongst the first to draw the metallurgical world's attention to the reducing power of the metalloids of cast iron when brought into contact with liquid oxide of iron.

It will be noted that so long as the iron in the slag remains above 20% the carbon and phosphorus are eliminated together freely.

In those cases where the bath is cold and the iron is about 12% in the slag the carbon is not oxidized as rapidly as the phosphorus, which agrees with results obtained by Sir Lowthian Bell in his washing process many years ago.

In Table III. will be found the analysis of the basic slag just before the furnace is emptied.

Table II. contains the weight of materials charged and yields obtained.

In obtaining 106 tons of steel for every 100 tons of metals charged we realize a very satisfactory result. This gain in yield has a beneficial effect in the cost sheet, and leaves a handsome margin after paying for the oxide of iron which is used to bring this about. It is a great contrast to the Bessemer, which wastes 13% or more of the pig metal to do the same work. This yield has been obtained with a low silicon metal, and will be increased with more impure metals, so that with this method we obtain exactly opposite results than with the Bessemer, for in the latter the more impure the metal the greater the loss.

The author considers that the method of working described in this paper offers advantages over the ordinary practice in many particulars. Amongst the chief of these may be cited:

1. The cost and delay in charging cold material is avoided.

2. A saving in fuel in charging molten pig iron, and also through not cooling the furnace by charging cold material.

3. The demand for a large and regular supply of good scrap, so important in ordinary practice, is wholly dispensed with.

4. A regular supply of steel to the mills in any wished-for quantity and at frequent intervals is insured.

5. An increase of output.

6. An increase of yield.

7. Less repairs to furnace.

8. Saving in labor charges, due to far less skilled labor being required per given quantity of steel.

9. The possibility of using very large furnaces, with consequent reduction in cost of production, without the necessity for very large cranes and ladles.

In conclusion, the writer must express his thanks to Mr. Percival Roberts, Jr., president of the Pencoyd Iron Works, for his unfailing support, and for allowing a special plant to be built wherein it was possible to obtain satisfactory and commercial results from the start.

The writer is also indebted to Mr. Anson W. Allen, chemist of the Pencoyd Iron Works, for the large amount of analyses which he has conducted in this research.

INDUSTRIAL EDUCATION IN AMERICA.*

Your committee on industrial education was appointed to make a report upon the educational means and methods which this society as an organization is prepared to commend to those who through benefactions or through administrative performance have it in their power to provide. By industrial education we here mean that education which specifically fits one for the industrial vocations or professions. This report has no reference to educational methods in general, nor to those special kinds of training leading towards the fine arts and to the learned professions other than engineering. Our problem is: What, in addition to the work that is now done in primary and secondary schools, is it wise for us to attempt to do in schools of various sorts for those young people who are looking for employment in our manufacturing industries, or in commercial houses, or with our great transportation companies, or in those new and more or less original adaptations of material means to social ends which are the peculiar problems of the engineering profession? If we can substantially agree on what ought to be done we can doubtless find the ways and means for doing it. The object of this report is to bring ourselves into substantial agreement as to what it is best to do.

Your committee are of the opinion that heretofore we all have relied too much upon specifics. We have also conceived the generic American boy as conditioned in a single way, and then have sought a solution which would fit this particular condition. Now the average or generic boy is no particular boy, and his average condition fits no particular case. But they are particular boys who are to be trained to do the business of the coming generation, and these particular boys are of all ages, conditions, tastes, and capabilities. Your committee are quite agreed that in America every boy should find his career entirely open at the top. Society here is not to be stratified horizontally, but, if at all, vertically. Our educational ways and means, therefore, must be planned for the purpose of helping every boy or man to make the most of himself, and hence to return to society the most he is capable of. But educational benefits cannot be conferred upon unwilling subjects, neither does the wish always bring the opportunity. Our industrial educational advantages and opportunities, therefore, should be both attractive and available to all classes and to all ages. Any boy or man wishing to improve himself, and to make of himself a more useful citizen, should find an opportunity for gratifying this high ambition. There are now in this country only the beginnings of systematic educational opportunities for boys and men to learn the theory and practice of particular employments for which they are fitted by nature and in which they long to become engaged. We have a superb system of public and endowed schools in which are more or less well taught the elements of knowledge and in which a very considerable mental capacity is developed. After leaving these schools our boys know something, so far as knowledge can be gained from books and oral instruction, but they can do little or nothing. This mental, abstract, and memoriter education needs to be supplemented by a manual, industrial, industrial art, commercial, or engineering education if the boy is to become a doer, or a director. He then not only knows something, but he can do something, and because he can do something he is worth something to society. However much a man knows, he is a drone in the hive if he cannot do something for the common good. It must be understood we are not asking for utilitarian education in place of a mind-informing and mind-developing education, but to supplement such cultural education as the boy or girl has been able to obtain. Neither do we care to insist upon young people availing themselves of this utilitarian education. We are only concerned that it should be offered, and we have every reason to believe that it will be a long time before the facilities will outrun the pressing demand for any kind of education which will enable a man to rise, in honor and in usefulness, in his chosen calling. We are not concerned to find the pupils, we are only concerned to provide the schools.

We are now to try to agree upon the various and sundry classes of theoretical and practical schools which are needed in every populous center in this country in order to meet all the educational demands now existing, to say nothing of the great increase in such demands as soon as we begin to meet them. While your committee may not quite agree in regard to the relative importance of the several classes hereinafter discussed, they are in substantial accord in affirming that all have their place in any thorough and general scheme of technical education for American youth. These classes of schools will now be described and discussed separately.

*Preliminary Report of a Committee of the Society for the Promotion of Engineering Education, Made at the New York Meeting of the Society, July 2, 1900. Signed, J. B. Johnson, C. M. Woodward, R. H. Thurston, H. T. Eddy, Geo. F. Swain and Edgar Marburg.

1. The Manual Training School.

There has probably never been a movement in American educational methods which has effected such great changes in so short a time as this manual training school movement. Growing out of the Russian educational exhibit at Philadelphia in 1876, the movement was given its American name, form and significance in the establishment of the St. Louis Manual Training School in 1880. To Dr. C. M. Woodward, a member of this committee, is due the credit of both the name and the thing as we know it in this country.* He also was its chief, and at times it seemed, almost its only advocate and defender. He has fixed it in America as a part of the general educational training of a large proportion of our boys who are not drawn especially towards the so-called classical courses of instruction. These schools need not be here described in detail. Suffice it to say they are intended for boys from 14 to 18 years of age, and they offer three or four years' courses. They divide their time about equally between manual exercises, drawing and laboratory work on the one hand and regular academic class-room work on the other. They make no pretense of fitting for particular employments, and in point of fact but a very small percentage of their graduates become and remain artisans. A very large proportion of them go into higher education, a majority of these very naturally taking the engineering courses.

The arguments in favor of these schools are, first, that they at present draw their students almost wholly from those who otherwise would leave school altogether at about the age of 14 or earlier; and, second, that for a very large proportion of city boys this is at present the best kind of a school they can attend at this age, no matter what they expect to do subsequently. For boys who expect to follow any industrial or commercial vocation, and who have grown up with little manual culture, as is the case with most city boys, the manual training school offers real and permanent advantages. Here the whole boy is sent to school and not merely his head, as Dr. Woodward has so tersely expressed it.

While these schools cannot be called industrial, since they fit for nothing in particular, they belong to the industrial class because the graduates from these schools are well fitted to go at once into any practical trade or business and learn it quickly and effectively. The boys from these schools are not too old or too lofty to enter the industries in the most humble positions; in this particular they have some advantages over the graduates from our high-grade engineering schools. While many of them may begin as artisans, they soon come to be foremen, draftsmen, salesmen, superintendents and the like, so that a census taken at any time will show very few of them in the artisan class. This fact, which is greatly to the credit of such schools, is frequently cited by shallow critics in disparagement of them. However, this fact has also gained for them the logical support of the artisan class, who at first were inclined to oppose them. Your committee are in substantial accord, therefore, in their belief in, and in their support of, the manual training schools as now organized and operated. They would like to see these multiply until every town boy can have the opportunity of obtaining this kind of education free of charge. The work should be adapted to girls as well as to boys. Thus for girls, cooking, domestic economy, sewing, dressmaking, etc., are introduced to offset the shop work of the boys. Whenever manual training is made a fixed part of the public school system, however, they most earnestly recommend to all public school boards a further development of the system, as described under the title of

II. Manual Training and Art Education as a Part of All Public School Education, from the Kindergarten Through the High School.

This we conceive to be the ideal method of introducing both manual and art training into the public schools. In two or three of the lower grades, sloyd work and simple hand-tool work might be employed alike for both boys and girls. Free-hand drawing also should be taught alike to all, and this should develop into graduated exercises of simple art designing, modeling, carving, water-color painting, carpet, wall-paper, and furniture patterns. Elementary needle work, cooking, and the methods of good plain housekeeping can be taught successfully to girls of the seventh and eighth grades. If suitable manual work be distributed over the entire public school period it would occupy but a very small part of the average daily program, and all such work would come as a rest and a recreation from the intellectual tasks assigned, so that instead of being a hindrance it would, in fact, be a stimulus and a substantial help in the regular class work. The bringing of these exercises into the regular school course would serve also to hold vast numbers in the schools who now lose interest and drop out for all sorts of frivolous reasons, which may be summed up in the two words, "lost interest." Many of our public schools are already moving in this direction. Perhaps the school which has realized this idea as completely as any is the central school at Menomonee, Wis. Here the management has had the wise counsel and the financial aid of a generous citizen, the Hon. J. H. Stout. He erected and equipped most liberally the necessary buildings, and has continued to pay the annual deficits in the expense accounts, but the city will doubtless soon be able to bear the entire expense, as the school has the loyal and enthusiastic support of the entire population. Both the appliances and the instruction in this school are of the highest order and the results are well calculated to astonish anyone who has never seen this system of public instruction in successful operation from the kindergarten through the high school.

This we conceive to be the ideal public school for America. It is expensive for three reasons: The buildings and equipment cost large sums; the instruction is of a high order and must be well paid for; and more than both these, the attendance will be greatly increased in the last six of the twelve years of the course, thus requiring additional buildings, plant, and teaching force for these grades. To fully carry out these ideas, therefore, will nearly double the running expenses of the schools and will add 50% to the building and equipment account. And yet your committee believes that this is the goal which we should strive to reach. We must learn first to spend wisely the money now raised in our cities for school purposes, and then we must almost double the amount.

America is far behind Europe, and particularly France, in all matters pertaining to either fine or industrial art. The highest industrial rewards come for new labor-saving devices and for new art-industrial designs. In the former we already lead the world, but in the latter we are far behind. Art can only thrive under conditions of general comprehension and appreciation. We need an art atmosphere. This requires time in which to educate the whole people along these lines, and to effect this the work must be done in the public schools. Even such artists as we have find a scant support because the masses of the people cannot distinguish between good and poor art, and furthermore they care little for art either good or bad. We are coming to be the richest nation in the world and can well afford to enjoy the highest fruits of wealth, one of which is beautiful and æsthetic surroundings.

But this æsthetic argument will have less weight with our people at this time than will the economic argument which goes with it. The world is now so far advanced in its appreciation of the beautiful that good art pays wherever it is coupled with the useful. Artistic design doubles the value of the product while it may not appreciably add to its cost of production. Almost all our artistic industrial designers now come from Europe. France fixes the fashions of the world because she is the acknowledged authority in art; and her supremacy in art is the very essence of all her material prosperity. But America is rapidly adjusting herself to this demand for more artistic productions and the time is ripe for the introduction of this art-industrial education in both our public and privately endowed schools.

III. The State Agricultural and Mechanical Colleges.

These schools are now found in one form or another in nearly every State in the union. Established originally under the several land-grant bills, most of them are now liberally supported by direct State aid, and they serve a very large constituency in the fields of agriculture, the mechanic arts, and engineering.

While the original purpose of the national appropriations was doubtless to train young men for actual practice in scientific farming and in other industrial pursuits, the students from these schools have very largely developed into civil, mechanical and electrical engineers. Comparatively few of them return to the farms, but many of them are found in the management of our manufacturing industries. These schools all give regular four-year college courses, but some of them have established short courses in agriculture. In Minnesota and in some other states to the "agricultural college" has been added an "agricultural school." This is a true secondary industrial school in which the art and science of farming is taught to both boys and girls. It teaches suitable English studies, physics, chemistry, the raising of crops, the use of fertilizers, animal husbandry, butter and cheese making, cooking, sewing and household economy. This course is wonderfully successful. Most of these schools, however, have not entirely fulfilled the hopes of their founders in supplying the much-needed school training to farmers and artisans, which was the primary and original purpose of these enactments. Many of them do form a most important class of engineering schools, since they accept students from the leading high schools of their respective states, and give them a sufficient scientific and practical training to make most useful members of the engineering profession in those grades which make up the great body of practicing engineers. They are near to the people, are comparatively inexpensive, and are very largely attended. These schools have thus more than justified their cost, though many of them are not altogether fulfilling their original purpose.

IV. The Higher Engineering Colleges.

These are strictly professional schools of a high grade which teach both pure and applied science and which rank with the best of their class in any country. Many of them are privately endowed and others are under the fostering care of the State, either as departments of the State universities or otherwise. In the training of professional engineers they are about all that could be desired; they are now, and have been for many years, turning out the most effectually equipped young men, in both theory and practice, that can perhaps be found anywhere in the world. These are to be the future leaders in the adaptations of the laws, the forces, and the materials of nature to the service of man. These are the men who, after some years of practice, can safely be entrusted to solve new problems both successfully and economically. They are the safe counselors and guides of the capitalist in all new mechanical ventures and they should be in constant demand by public officials, by boards of directors and by individuals in all cases where large expenditures are to be made, or where important definite results are imperatively required. The scope and purpose of these schools are, however, well understood by our people and they need not be further elaborated here.

V. Monotechnic, or Trade Schools.

These schools are comparatively new to the American people. They have long been in operation abroad, and are most fully developed in Germany. But the foreign pattern is not well suited to American needs. There a boy's career can be marked out for him in advance. If he is to be an artisan he is expected always to remain an artisan. The particular trade which he is expected to learn, also, is fixed for him. It is commonly that of his father before him, or that of the prevailing industry of the locality. He is at best a sort of machine, an automaton, worked for what he is worth to the family or to the community and the state. His own individual development is not in question. Most commonly he is not even consulted in the matter. His future is his fate, and he yields to it as gracefully as he can. He has little opportunity to rise above the station in which he finds himself. His career is closed in at the top. Society is stratified horizontally. He finds such solace and comfort as he can by ministering to his bodily comforts and his domestic joys, and frets not over vain ambitions. In fact, ambition is a word of little meaning to him, since it can have for him no satisfactory fruition. In these foreign countries, therefore, the trade school is primarily a means of more efficient and more economic production, and only incidentally is it a means of personal development.

In America all schooling should lead primarily to the elevation and development of the individual, and only secondary to a greater material prosperity. It is for this reason that the European trade-school idea makes headway so slowly in this country. If we teach a boy a trade it is not only that he may practice it, but that he may become a master workman, an employer, a contractor, a manufacturer, a proprietor, a leader in his calling, and withal an influential citizen and a director of public affairs. We always want to teach him many things besides the mere manual performance and the more or less scientific theory which accompanies and underlies such performance. It is not necessary, however, to teach all these things in the trade school. We shall continue to rely upon the public schools for the general education. The trade school with us must supplement this, and not displace it. It remains for us to work out a system of trade schools suited to our needs.

The need for industrial training in the various practical vocations and trades is becoming daily more apparent. Not only are more vocations becoming more scientific and less traditional in their practice, but the wholesale introduction of labor-saving machinery and the abandonment in large measure of the apprenticeship system, leaves our boys and young men absolutely without opportunity or resources in entering successfully any of these practical callings. In addition to these inherent obstacles, the rules of the trades' unions by which the admission of learners is limited to a very insignificant number, still further shut out young men from all lines of productive employment. In very many cases not even the proprietor's son is allowed to learn the business practically, or if perchance the permission of the union be extended to him to enter the works as a learner, he must beware of his steps, for pitfalls are set for him at every turn and even his life may be in danger. This is a grave mistake of judgment on the part of the unions, as we are convinced.

It has come to such a pass, in fact, that the avenues by which American youths can learn almost any practical calling in all its details are almost absolutely sealed up. The only recourse is the teaching of all these trades and employments in especially equipped schools. If the would-be apprentice hopes to become anything more than an average workman, he must learn the scientific and practical elements of the business somewhere, and it is well established that he can learn them most successfully in properly operated schools. These schools should not individually attempt to teach too much; they should, however, teach the underlying scientific principles of one or two trades thoroughly, as well as the most approved commercial practice. The practice, however, is the most difficult to teach in the school. In the first place it is hard to find persons having both the practical knowledge and the teaching ability. To impart practical knowledge rationally one must rest it on some scientific or rational

*It hardly need be said that Dr. Woodward is not responsible for the insertion of the above claim in this report.

basis, and not simply upon the dictum of tradition. This rational basis of trade practices is commonly either entirely wanting, or if it exists at all it is quite unknown to the practitioner. His reasons for his doing a thing so and so are usually far from sound. Competent instructors in the practical trades are, therefore, very difficult to find.

In spite of all these difficulties very efficient trade schools are being established and others are called for by the proprietors and managers of various industries. At the last meeting of the American Foundrymens' Association, held in Chicago, June 5-7, 1900, a resolution was adopted calling for high-grade industrial schools to teach the science and art of founding. The school in clay industries, started a few years ago at the University of Ohio, has already resulted in the establishment of new ceramic works of very great promise; as a rule the expense of establishing and maintaining these schools should be met by industrial corporations, or by individuals, or by the joint action of manufacturers, locality, and State. Some of the more important industries now requiring such schools will be named.

(1) The Textile Industries.—These are one line of industries which most readily submit themselves to monotechnic or trade-school instruction. Trade schools in these industries have long been common abroad and a most successful one has been in operation for many years in Philadelphia. A number of new ones have recently been established in New England. The State of Massachusetts makes a standing offer of $25,000 assistance to any city or corporation in the establishment of a textile school which complies with certain requirements. In the higher textile schools the science of dyeing and the art of designing are taught as well as the practice in weaving and finishing all grades of fabrics. These higher courses are several years in length and are best pursued after taking a high school or manual training school course. Even a college or an art school, or an engineering school preparation before entering the textile school, is none too much if one wishes to fully master the industry, to understand the mechanical and the power plants, and also to become familiar with the business departments of the manufacture and sale of textile fabrics on a large scale. Many of the highest and latest developments of the science of chemistry find their application in the dyeing of yarns and fabrics, and the large dyeing and printing works in Germany have many chemists constantly engaged in studying new and improved applications of chemical knowledge to the textile industries.

(2) The Machine Trades.—These are at the basis of all manufacturing, and superiority in these very largely sustains our modern national prosperity. The fundamental principles and most of the practice of these industries can best be taught in schools having proper equipments. The recent general introduction of automatic and labor-saving machine tools, and also of tools of extraordinary size, has, however, created a demand for an entirely different class of workmen. Formerly a great deal of hand work was done and every journeyman in the shop was expected to be able to perform almost any task in the ordinary routine of shop duties. This demanded a long apprenticeship in actual shop practice and the acquisition of high manual skill. Now the average workman in our large shops is only a machine attendant, and he is kept employed with a single class of machine tools. His business is to learn the capacities of this tool and to get the most work out of it of which it is capable. In fact, some of our most progressive superintendents affirm that they prefer these narrow specialists to the old-fashioned all-around machinists. For a tool attendant of this class very little general training of any kind is required. With good instruction he will learn in a few days, or perhaps hours, to operate the machine intelligently and very soon he will be working it to its full capacity. Trade schools are not a necessity for these men. This system carries in it, however, the seeds of its own destruction. By this system no one man is learning the business in its entirety, and hence no one is being trained to superintend or manage the business both theoretically and practically. The graduates of our colleges of mechanical engineering would make the most capable men for these higher positions of superintendence if they would be willing to enter the shops, after graduating from the schools, and learn all the practical details of the business. This they often are not disposed to do. Failing of these the graduates of our manual training schools would serve very well for those positions of trust and supervision. These are more ready to enter the lower ranks of mechanical employment and work their way to the top. By systematic apprenticeship in the shops, these young men would readily develop into very good foremen, superintendents and managers. In some cases, however, the trade unions would seriously interfere with any free application of this sort of a program.

Again it must not be forgotten that many of our most ingenious and capable machinists and mechanical inventors, and who have become the proprietors of the finest machine-tool works, have had no special technical education, but have come up through the old system of apprenticeship. To save this class of talented young men to the business, and to enable them to more fully master an industry now that the apprenticeship system has been practically abandoned, some means should be provided for giving them what the former system gave, and which the technical and industrial schools are giving to their students. These men will not leave their employment and go back to the schools. Such schooling as they are ever to receive must be brought to them. It is probably true that many of the most capable of these men will now find some means of acquiring a technical education before entering upon industrial employment, whereas formerly apprenticeship was the only way open for entering these employments. It is probable, therefore, that only a few of the actual uneducated workers in the shops to-day will care to avail themselves of any school opportunities, however convenient, but these few are the ones who would profit most by such training. These may, with some technical instruction, become leaders and directors of their fellows, and the rest may remain automatic attachments to their mechanical tools if they choose, without seriously impairing the success of the works and the local and general prosperity resulting therefrom. This is the hardest, though not the largest and most important, problem your committee has had to struggle with. How are we to furnish adequate instruction to those young men who will have had no opportunity to secure a technical training, but who, after entering upon some industrial calling, wish to remedy this defect of early education? Such answers as we are able to make are contained in the next section of this progress report. Since nearly all industrial production to-day is mechanical, the solutions which are offered for the technical training of machinists will apply very largely to all workers in all lines of mechanical production.

VI. Supplementary Schools for Industrial Workers.

These are schools for those bright and promising boys and young men who have from choice or from necessity already gone to work in some industrial calling with little or no scientific or technical schooling, as well as for those boys who can be reached by no other class of industrial or technical schools. The present demand for these supplementary schools is very large, but with the general introduction of manual, scientific and art education into the public schools, the demand for such supplementary schools will be very greatly reduced. The most promising foundations for the organization of these schools your committee believe to be the following:

(1) Proprietary Trade Schools in Connection with Industrial Works.—Nearly all lines of production are now organized into a few great manufacturing centers, and all the factories of any one class in the whole country are more than likely to be operated by a single joint stock company. This company shapes the industry over the whole American continent. We believe it will be profitable in all these great industries to establish industrial schools in connection with all their large factories in which a few of their brighter workmen can be educated, not only in all parts of their business, but in the underlying and related sciences, in order to become capable foremen, superintendents, and inventors. These are at least a large portion of the men the stockholders must look to for continued improvements, for skillful management, and for economic operation. After we have passed through the stock-jobbing stages of these new and mammoth combinations, we will surely come around to this basis of most economic production and safe business management. The machine attendants will commonly be taken from the ranks of unskilled labor. These can be taken on and put off at pleasure, and they will be found in that large class of happy-go-lucky individuals who find self-improvement too laborious and confining, and who feel that sufficient to the day are both the good and the evil thereof. In those industries where perfection of workmanship is a prime essential, even the machine attendant must be a bright, skilled, thoughtful, attentive man or woman, and in these works some educational stimulus and some rewards for acquired competence and for fertile suggestions will be found to be not only fair dealing but a most profitable business policy. We are now passing rapidly through an evolutionary if not a revolutionary stage in these matters and our general managers of large works are coming to realize the necessity of an educational side to their business. It is said of Americans that they are quick to see opportunities of improving their business and are ready to adopt any measure which promises a sufficient return for the outlay. Your committee felt that these proprietary schools in connection with industrial works would make their own way in this country without any organized campaigning, but some systematic effort to present their advantages will hasten their general introduction. Whether these schools take the form of night schols, of half-time day schools, or of financial aid to the brighter lads to attend some specific courses in a technical school, or all of these combined, is not now material. That all of our large industrial works and combinations of works should be brought to see it to their interests to furnish supplementary school facilities to their brightest boys is the problem which now presents itself to those who wish to further the course of industrial education in this country. Railway corporations, and large mechanical, electrical, and chemical manufacturing companies will probably draw all their technically trained men from the regular engineering schools in preference to establishing technical apprentice schools. These are then given a few years of systematic shop experience which serves as their industrial apprenticeship. Some of our railway companies are introducing also apprentice school instruction into their large construction and repair shops.

(2) Correspondence Technical Schools.—These have sprung up like magic in America in the past ten years and are now serving a great need. Whether they will remain in demand or are only a passing phase of educational opportunity may be a question. Until other opportunities of acquiring a technical training become practically universal, however, it is very clear that they will find a great work to do. The fact that a single one of these schools (the oldest one) is now carrying on its roll of students over 100,000 names is the best proof of the great need of some form of supplementary technical education. These schools supply their students with specially prepared texts, and have systematic correspondence methods of imparting instruction. If the student is willing to do his part he may obtain in this way a very fair substitute for a school training. He lacks the stimulus, however, of a direct personal contact with a teacher and with other workers in the same subjects. A very large majority of the students who begin in these courses become discouraged, or find themselves overburdened, or else have not the requisite application, and so stop work in the early stages of their correspondence courses. This is not surprising when the persistent, systematic, and seductive methods of obtaining subscribing students are fully understood. Still the truth remains that if a young man really wishes a technical education and is willing to do his part, he can get considerable assistance in this way, be he in the slums of a large city, or on a cattle ranch in Texas, or in the South African gold mines. And these necessities of the isolated learners will probably always make a large demand for correspondence instruction, no matter how general other means of acquiring a technical education may become. These schools are but another evidence of the quick initiative of Americans. The demand was no sooner felt than the supply was forthcoming in this new and original kind of a school.

(3) City, Endowed, and Y. M. C. A. Night Schools.—These are designed to serve young men who are employed throughout the day. They are quite similar to such schools abroad. The student comes two or three nights a week from 7 or 8 to 10 o'clock. He comes more or less worn out by his day's toil and he reaches home long after his usual retiring hour, practically exhausted. His mind cannot be alert with his body in a fagged-out condition and hence this class of instruction is at once a great hardship and of relatively little profit. Men who are engaged in any kind of actual manual labor through the day cannot be greatly benefited by attendance upon such schools. They are most valuable for clerks, bookkeepers, draftsmen, and the like. They can never become a very substantial element in the technical education of the industrial classes.

But besides the inherent weaknesses of these night schools we find they are not commonly well taught. The teachers are changed from year to year, and there is no fixed policy or line of study. These teachers also are not commonly experienced in imparting instruction and the whole atmosphere of these schools is apt to be very far from stimulating and invigorating. Sometimes Sunday technical schools have been tried, but they are not likely to be very large introduced or patronized in this country. These supplementary night and Sunday technical schools, therefore, are never likely to perform a very important function in giving to young men in America a higher technical development or in preparing them for a greater service to society. They are good as far as they go, and should be encouraged and well supported, but they are at best a poor expedient and cannot be regarded as anything like an adequate means of self-improvement for our industrial workers. Professor Woodward, who tried for four years in St. Louis the experiment of a "Sunday morning technical school," is of the opinion that such schools could be made very successful if properly equipped and made permanent in any industrial community. An American community must first get used to the idea.

(4) Half-time Self-supporting Trade Schools.—This class of schools has recently been ably advocated by Mr. M. P. Higgins, in the Proceedings of the American Society of Mechanical Engineers. Mr. Higgins was for 20 years in charge of the shop instruction given in the Polytechnic Institute of Worcester, Mass. He states that the experience of that institution justifies the claim that well equipped and officered industrial works, as, for instance, large machine-tool or engine works, joined to good technical schools, could be made to pay a very large proportion if not all of its running expenses. In such a school the boys would spend half the day in the school and the other half in the shop. They would pay little or no tuition, but they would receive nothing for their work. The school would be divided into two divisions and these would alternate in school and shop work. A sufficient number of expert machinists would be regularly employed to oversee the shop work of the boys and to impart the shop instruction, while the theoretical or school work should be given also to both forenoon and afternoon sections by another set of technical instruc-

tors. In this way very nearly actual shop conditions could be introduced, and the advantages of the old apprenticeship system could be retained in addition to the further benefit of a regular school training. If such a system of trade schools be practicable they may go a long way towards furnishing a final solution of the great problems of the industrial training of the rising generation. It is to be hoped Mr. Higgins will find the means of embodying his ideas in an actual combined shop and school as he proposes, and so proving the practicability and efficiency of his plans by an actual test. For such a trial the most favorable conditions should be secured, the most competent instruction obtained, and the best possible shop equipment purchased. It is vitally important that the first trial of such a plan should be given every fair advantage to prove its worth. If it succeeds, as its chief advocate promises that it will, it may mark the beginning of as great a movement in industrial education as the manual training school has done in general education. There is no middle ground between the expert machinist and the mechanical engineer. The difference is one of degree rather than of kind. These half-time schools would turn out expert machinists, many of whom might become skillful mechanical engineers.

(5) Public Libraries and Scientific, Technical and Trade Journals.—We must not forget that every man who has come to anything is almost wholly a self-made man. This is particularly true in America, and applies to mental as well as to material acquisitions. The mental asmosphere which pervades our great industrial work is always bracing and sometimes stimulating. If free public libraries are not conveniently available a free proprietary library and reading-room at the works can readily be established. Here all the current technical and trade journals can be kept on file, and those employes who are capable of a large development will find here their mental nourishment. It is, we think, not too much to say that in almost every industry there are now both books and technical and trade journals of a very high educational value which can be continually added to at a small cost. If these reading-room facilities are wanting, therefore, any ambitious boy or man can take one or more of these journals and by studying these and a few well selected books, he can acquire a very fair scientific knowledge of his calling. A generation ago these also were entirely wanting, so that then, with neither schools, books, nor journals, the only possible means of acquiring a knowledge of any industry was through a long apprenticeship in the business itself. But now if both the systematic apprenticeship and the technical schooling be wanting, there still remains a flood of printed matter in books and journals from which a young man can, if he will, obtain a very fair theoretical grounding in the manufacturing or commercial industry in which he is engaged.

VII. Higher Colleges of Commerce.

These are common upon the continent of Europe, but have never obtained recognition in England or America. They are now being strongly urged upon our people, and a number are likely to be established in the immediate future. In these a full four-years' course of instruction of college grade will be given. The work will include a writing and speaking knowledge of one or two foreign modern languages; a wide acquaintance with commercial geography and the materials of commerce; full courses upon means and methods of transportation and shipping regulations of various countries; commercial law and customs regulations, both foreign and domestic; the laws and practices of banking and exchange; political and economic science; mediæval and modern history; history of commerce and manufacturing; consular duties, regulations and reports; international business law; and other subjects which can be taught and which will help to qualify a young man for a responsible position in a large business having foreign relations, or as a United States Consul. It will be men having such an education to whom we must look for a successful competition with Germany in our foreign commerce. But we have already seen the necessity for these schools, and we may confidently anticipate their rapid and successful establishment. We must guard against making the mistake of merely grouping together a series of subjects now taught in our schools, and calling that a course in commercial education. The work must be technical, and immediately available and useful rather than general and cultural. The subjects must be taught, therefore, in a way quite different from the way they are taught in our literary colleges. This will require separate class organizations and very largely separate instructors, when the school of commerce is made a part of an existing college or university. These schools will therefore be expensive. There should also be in connection with every such school a well-equipped commercial museum, in which are kept for examination and study, nearly all the ordinary articles of commerce in both the raw and the manufactured state. These schools would then stand in a complimentary relation to the higher industrial and engineering schools. While the latter train the captains of industry, the former train the men to exploit the products of these industries in all foreign countries. One is as essential as the other. With both our material supremacy is assured for all time.

The above is offered as a hasty and provisional review of the field of industrial education in America, and as a progress report of your committee. The committee has had to do all its work by correspondence, several of its members being out of the country at the time of this meeting. If the society decides to continue the committee they will try to make a more mature report, with recommendations, at a later meeting of the society. To assist them in their work they hope to secure at this meeting a general expression of the views of the members, and of others who are exceptionally well informed in these matters, and whom the committee has invited to be present at this session and to participate in the discussion. The duties of the committee are not clearly defined, but we have assumed them to be the critical analysis of existing and proposed methods of industrial education at home and abroad, and the endorsement of those which we find to be best suited to American needs.

ANNUAL CONVENTION OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

The eighth annual meeting of the society was held at Columbia University, New York city, July 2 and 3. About fifty members were in attendance. In the absence of Professors Ira O. Baker and Edgar Marburg, president and secretary, respectively, Prof. Robert Fletcher acted as president and Albert Kingsbury as secretary. President Baker's address was read by Prof. J. M. White, of the University of Illinois. It reviewed the growth of engineering schools, and included a number of statistical tables showing their present status. Three of these tables, giving the number of institutions offering various courses, the number of students in each course during the college year 1898-9, and the total number of graduates, by courses, in 1899, have been condensed and combined into the accompanying table.

Statistics Relating to Engineering Schools in the United States, 1898-9.

		Institutions offering courses[1]	Students in 1898-9.	Graduates in 1899.
Courses in	Civil engineering	67	2,667	419
	Mechanical engineering	61	3,293	480
	Electrical engineering	49	2,397	370
	Mining engineering	21	860	78
	Architecture	15	389	56
	Naval architecture	2	54	9
	Sanitary engineering	2	19	1
	Total	..*	9,679	1,413

[1] 1898-9.
*89 different institutions.

Attention was called to the fact that in 23 institutions the post-graduate students in engineering were only 2.3% of the undergraduates, while in the other departments the percentage of post-graduates was four times as great. Professor Baker gave a number of reasons for the relatively small number of post-graduate engineering students, the chief of which was that the engineer has plenty of opportunity for research work in the regular practice of his profession.

The first paper after the address by the president was "Personality in Teaching," by Prof. John P. Brooks, of the State College of Kentucky. He thought that the expensive material equipment of many schools, with the numerous assistants necessary to care for and operate the apparatus, tended strongly to curtail the funds available for offering inducements to the highest class of instructors, particularly men with strong personalities. This opinion was shared by many who took part in the discussion, but Prof. J. B. Johnson, of the University of Wisconsin, voiced another phase of the question when he declared that it is impossible to get a man with strong personality unless the institution in question possesses a good equipment. Some institutions, however, have the equipment without the personality.

"Business Methods in Teaching Engineering" was the title of the next paper. The author, Prof. Arthur L. Rice, of Pratt Institute, held that the actual methods of the business world should be used in engineering schools, where available. He described some of the forms for reports and various other business methods in use at Pratt Institute, laying particular stress upon measures taken to secure the doing of work on time. Prof. Henry S. Jacoby, of Cornell, said that he deducted 10% per day from credit marks for delays in filing reports.

The whole of the session on Monday afternoon was devoted to the presentation and discussion of the report of the Committee on Industrial Education. The report was read by the chairman, Prof. Johnson. It is published in full elsewhere in this issue.

The discussion on this report was opened by the reading of a letter from Prof. T. C. Mendenhall, of the Worcester Polytechnic Institute. He cordially approved the report, in the main, but said that the materialistic tendencies of the time demanded caution on the part of those engaged in educational work. A number of gentlemen, not members of the society, were present and took part in the discussion, by request, including Col. H. G. Prout, of the "Railroad Gazette"; Mr. M. P. Higgins, of Worcester, Mass.; Mr. R. P. Rothwell, Editor of the "Engineering and Mining Journal"; Col. E. D. Meier, of New York, and F. A. Halsey, Associate Editor of the "American Machinist." A number of members also participated in the discussion. On the whole, the various speakers commended the report most heartily. Col. Prout said he had visited a number of engineering schools recently and was amazed to see their liberalizing tendency. Mr. Rothwell made a bold stand in favor of correspondence schools, stating frankly that he was president of one, and believed the fact that these schools are primarily money-making institutions is in their favor, since their promoters and backers have their financial interests at stake. Free schools, he said, were poor schools, a sentiment that did not arouse much enthusiasm, as may readily be appreciated. Mr. Halsey said there is at present a crying need for foundrymen's schools.

A large part of Tuesday forenoon was devoted to the reading and discussion of a paper by Prof. Robert Fletcher, of Dartmouth, on the "Present Status and Tendencies of Engineering Education in America," and another by Prof. Wm. G. Raymond, of the Rensselaer Polytechnic Institute, on "The Promotion of Engineering Education." Professor Fletcher referred to some of the faults of the secondary schools, due to mistaken ideas and methods, and raised the question whether in the engineering schools the pressure for a large range of studies did not result in quantity rather than quality. He also emphasized the desirability of so adjusting all the factors in the education of the engineer as to produce a "well-educated man," and not a mere specialist. Professor Raymond discussed the requirements of the graduate engineer and aroused much discussion by seeming to question the character of the work of the engineering schools. He subsequently explained that this questioning was designed to bring out the ideas of those in attendance.

Of the remaining papers (see full list in our issue of June 21) many were read by title. Some of the others we abstract briefly, as follows:

Original Investigations by Engineering Schools a Duty to the Public and to the Profession.

By Prof. A. Marston, Iowa State College.

The author called attention to the large amount of investigation work now done in engineering schools. The writing of books on engineering subjects is considered to require original investigation of the highest grade, and statistics were given as to the large proportion of recently published technical books whose authors are professors at engineering schools.

The influence of such investigations is very great in arousing professional enthusiasm among the students and in predisposing them to original thought and investigation in their future engineering work. Bright, reliable students can often be employed in the simpler work of such investigations, but they should always work under the close supervision of a responsible instructor.

Investigations which should be carried out at engineering schools are of two general kinds: (1) Investigations mainly of professional interest and value; and (2), investigations whose results have a considerable commercial and industrial as well as professional value.

As to investigations of the first kind, the paper calls attention to the fact that lack of leisure, scientific apparatus and laboratory facilities must in the majority of cases prevent practicing engineers from investigating experimentally the many new problems which arise in their work. It is a duty of engineering schools to the profession to help advance engineering knowledge by carrying out such investigations, and all schools should have proper facilities for such work.

The Relations of the Technical School and the Manufacturer.

By Prof. Walter B. Snow, Jamaica Plain, Mass.

The interdependent relations of the technical school and the manufacturer present many opportunities for mutual helpfulness. The school may serve the manufacturer by supplying men especially equipped for his work; by giving publicity to the results of his investigation, possibly by carrying them on at his suggestion and expense; by furnishing information regarding technical matters; by opening to him its libraries, its periodical literature, its museums, or even its laboratories; and by acquainting the students with worthy products of his manufacture.

The manufacturer, on his part, may be of assistance in determining the most suitable courses of practical study. He may suggest practical subjects for investigation, and provide apparatus, materials and facilities. He may show the latest state of the art by lectures, catalogues, drawings, photographs, models and working apparatus, and his works may be thrown open for visits of inspection. By special concessions in price he may be of financial assistance in the equipment of buildings and laboratories.

Minor Considerations Affecting the Arrangement of a Course of Study in Civil Engineering.

By Prof. Henry S. Jacoby, Cornell University.

This paper considered, first, the distribution of the actual time devoted in a course of study in civil engineering: To (a) lectures and recitations, (b) drawing and the related computations, (c) laboratory work, field-practice and physical culture.

Attention was called to the claims for variety in the work of each day as well as that of each week. Among the other questions considered are the following: What weight should be given to the values (to both students and instructors) of concentrating effort upon fewer subjects during a given period? What is the relative value of greater intensity in study for a shorter period, and of more leisurely study extending over a longer period? To what extent does the frequency of recitations or other exercises promote sustained interest in this subject?

A word may be said regarding Prof. White's paper on "The Development and Practice of Architecture," in which the author brought out the deplorable fact that the architectural schools of merit in this country are few and not remarkably well patronized. Germany, with a smaller population than the United States, has four times as many architectural students.

The election of officers for the ensuing year resulted as follows: President, Professor Frank Marvin, Lawrence University, Lawrence, Kan.; Secretary, Henry S. Jacoby, Cornell University, Ithaca, N. Y.; Treasurer, C. A. Waldo, Purdue University, Lafayette, Ind.